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School of Mechanical Engineering

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Development of a process reference model for construction supply chains: the contractor's view

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Διδακτορική Διατριβή
προς το
Εθνικό Μετσόβιο Πολυτεχνείο

Τμήμα Μηχανολόγων Μηχανικών

Τομέας Βιομηχανικής Διοίκησης & Επιχειρησιακής Έρευνας

Ανάπτυξη μοντέλου αναφοράς διαδικασιών εφοδιαστικών αλυσίδων για τον κλάδο των κατασκευών: η οπτική του ανάδοχου έργων

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Διδακτορική Διατριβή
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Τίτλος Διατριβής	«Ανάπτυξη μοντέλου αναφοράς διαδικασιών εφοδιαστικών αλυσίδων για τον κλάδο των κατασκευών: η οπτική του ανάδοχου έργων»

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Essentially, all models are wrong, but some are useful.
George E.P. Box (1919-2013)

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Abstract

The construction industry has been described by its clients as ineffective and lacking innovation. There have been many studies aiming to identify the causes of these problems and to provide applicable solutions. One of the proposed solutions is the adoption of supply chain management principles by all actors in the industry (clients, contractors, subcontractors, etc.). Supply chain management in the construction industry has been studied over the past twenty years, and once debates on its applicability in the industry were settled, research took off. Construction supply chain management is a novel research field and construction practitioners are not informed about the progress made in academia. The focus of this dissertation is on contractors as they have direct contact with the client. Clients in the in the construction industry have a huge impact on the end product as they set the requirements for each project. Contractors cannot afford to cover all client requirements internally and turn to subcontractors and material/service suppliers to cover this gap. This makes contractors the most important link in a project's supply chain. Construction practitioners in contractor organisations are aware of the concept of processes as it is part of their daily routine. This provides fertile ground for the description of the contractors' supply chain through a process view. The aim of this dissertation is to provide a process reference model for construction supply chains focussing on the contractor. In order to achieve this, a demanding but straightforward methodology is employed. A literature review identifying the characteristics and particularities of the industry, defining the concept of construction supply chain management and analysing previous studies is performed. This provides the background for the creation of the process reference model. Next, an existing supply chain management process reference model is selected to provide the backbone of the model proposed. This model is adapted to the construction industry based on the results of the literature review. A process modelling tool that can depict multiple views of supply chain processes is selected to support the modelling effort. The literature is studied further in order to create a process reference model that considers as many aspects of the construction supply chain as possible. These aspects are grouped into nine functions: determine supply chain management strategies, client relationship management, new project development, supplier relationship management, develop key performance indicator framework, demand management, work package management, construction flow management, and claims management. Each of these functions contains a number of strategic and operational processes. These processes are based on best practices identified in the literature and are validated and enriched with undocumented best practices through semi-structured interviews with experienced senior staff of both SME contractors and large contractors. This ensures that the model can be implemented by most contractors in the industry. Furthermore, the analysis of the interviews provides insights to the differences in supply chain management practices of the different sized contractors. The value of the proposed model lies in the fact that it not only describes construction supply chain management functions and processes at a high level, but it also describes the requirements for its adoption and implementation. It can prove useful for both academics and practitioners. It provides academics with a tool to integrate the provided processes with other supply chain views such as risk management or decision support systems. Practitioners can benefit from the specific characteristics of the model (structure, verbal and diagrammatic descriptions, developed in free software) in order to improve, benchmark and compare the performance of specific project supply chains or the performance of their entire supply chain practices and strategies.

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Part 1 – Μέρος 1

Εκτεταμένη σύνοψη

Πίνακας Σχημάτων

Πίνακας Πινάκων

1. Εισαγωγή

Ο κλάδος των κατασκευών έχει επικριθεί σφοδρά για τις πρακτικές του και από την ακαδημαϊκή κοινότητα και από κυβερνητικούς οργανισμούς σε όλο τον κόσμο. Η κριτική εστιάζει στην αδυναμία του κλάδου να διαχειριστεί με επιτυχία δραστικές αλλαγές (Edum-Fotwe et al. 2004). Ο Baldry (1997) εντόπισε ότι η κοινή αντίληψη για την εικόνα της κατασκευαστικής βιομηχανίας είναι αυτή μίας βιομηχανίας που: 1) παρέχει ένα μη ικανοποιητικό και συνήθως με καθυστέρηση προϊόν, με περιορισμένες υπηρεσίες φροντίδας μετά την παράδοση του προϊόντος, και με επιβάρυνση των καταναλωτών με υπέρογκα και απρόσμενα κόστη, 2) είναι εργοδότης ενός κακόφημου, ανδροκρατούμενου εργατικού δυναμικού το οποίο επιδεικνύει αναξιοπιστία, χαμηλή παραγωγικότητα, και περιορισμένες ικανότητες και δεξιότητες, 3) εφαρμόζει ξεπερασμένες πρακτικές και η χρήση της σύγχρονης τεχνολογίας είναι ασυνήθης και αναποτελεσματική, 4) προσφέρει πεδίο για πρακτικές διαφθοράς που εξαπατούν τον πελάτη και τις φοροεισπρακτικές αρχές, 5) είναι πηγή διαταραχών στην προσωπική ή επιχειρηματική καθημερινότητα, 6) λεηλατεί φυσικές πηγές και καταστρέφει το φυσικό περιβάλλον, και 7) προσφέρει μη ικανοποιητικές προοπτικές καριέρας που συνοδεύονται από υπερβολικές εργοδοτικές απαιτήσεις. Το κύριο προϊόν της κατασκευαστικής βιομηχανίας είναι το κατασκευαστικό έργο. Οι Dubois και Gadde (2000) περιγράφουν το κατασκευαστικό έργο ως ένα προσωρινό δίκτυο συμμετεχόντων που διαλύεται με την περάτωση των εργασιών ολοκλήρωσης του έργου. Έτσι, σύμφωνα με τους Akintoye et al. (2000), ασκείται πίεση στον ανάδοχο ενός έργου να αναπτύξει ικανοποιητικές δομές και αποδοτικά συστήματα επικοινωνίας για την αποτελεσματική διαχείριση των σχέσεων ως μέρος της διαχείρισης ενός έργου. Η πρόσφατη μεταβολή των απαιτήσεων των πελατών από αμιγώς οικονομικές σε απαιτήσεις για καινοτομία, βιωσιμότητα και ταχύτητα έχει δημιουργήσει την ανάγκη να αναπτυχθούν στενότερες σχέσεις με τους υπεργολάβους και αναδεικνύουν τη σημασία της διαχείρισης των προμηθευτών (Bemelmans, Voordijk & Vos 2012b). Αυτό το γεγονός έρχεται να προστεθεί στην υφιστάμενη μεταβίβαση των ευθυνών από τους πελάτες στους αναδόχους που οδήγησε στη χρήση ολοκληρωμένων συμβολαίων (Bemelmans, Voordijk & Vos 2012a). Η ολοκλήρωση απαιτεί τη διαχείριση των διεπιχειρησιακών ροών, διαδικασιών, συστημάτων και παραγόντων (Bankvall et al. 2010). Ωστόσο, η κατασκευαστική βιομηχανία αντιμετωπίζει προβλήματα που σχετίζονται με τη διαχείριση των εφοδιαστικών αλυσίδων και, έτσι, η προτεινόμενη ολοκλήρωση στις διαδικασίες δεν μπορεί να επιτευχθεί (Briscoe & Dainty 2005).

Ο σχεδιασμός και η διαχείριση εφοδιαστικών αλυσίδων απαιτεί τον κατάλληλο προσδιορισμό των μερών που συμμετέχουν σε αυτές και των σχέσεων αναμεταξύ τους (Cheng, Law, Bjornsson, Jones & R. Sriram 2010). Η διαχείριση των εφοδιαστικών αλυσίδων πρέπει να βρεθεί στο επίκεντρο των στόχων που θέτουν οι ανάδοχοι για την διαχείριση ολικής ποιότητας (Wong 1999). Οι ανάδοχοι πρέπει όντως να αναπτύξουν ικανοποιητικές δομές και αποδοτικά συστήματα επικοινωνίας για την αποτελεσματική διαχείριση των διεπιχειρησιακών σχέσεων ως μέρος της διοίκησης έργων και της διαχείρισης εφοδιαστικών αλυσίδων (Taylor & Levitt 2004). Η εφαρμογή των αρχών της διαχείρισης εφοδιαστικών αλυσίδων στον κλάδο των κατασκευών έχει κατά κύριο λόγο συνδεθεί με συνεργατικά συστήματα προμηθειών, μακροχρόνιες σχέσεις και συνεταιριστικές πρακτικές (Vidalakis et al. 2013). Ωστόσο, η υφιστάμενη θεωρία της διαχείρισης εφοδιαστικών αλυσίδων δεν μπορεί να εφαρμοστεί αυτούσια στην κατασκευαστική βιομηχανία και είναι απαραίτητη η προσαρμογή των εννοιών, πρακτικών και τεχνικών της στις ανάγκες του κλάδου (O'Brien et al. 2004). Παραδόξως, η προσοχή που έχει δοθεί στις εφοδιαστικές αλυσίδες του κλάδου είναι ελάχιστη (Vidalakis et al. 2013). Για παράδειγμα, τα logistics πρέπει να ενσωματωθούν στη διαδικασία της κατασκευής (Agapiou et al. 1998) έτσι ώστε να επιτευχθεί εξοικονόμηση κόστους της τάξεως του 10-30% στα κόστη κατασκευής (Rogers 2005) και να μειωθούν τα κόστη που συνδέονται με ποιοτικές παρεκκλίσεις κατά 3,4-6,2% (Thomas et al. 2002). Στις περισσότερες των περιπτώσεων, μια εφοδιαστική αλυσίδα περιγράφεται ως ένα δίκτυο παραγόντων ή ένα δίκτυο διαδικασιών και δραστηριοτήτων (Harland 1996). Εντούτοις, η αλήθεια είναι ότι διαχείριση των εφοδιαστικών αλυσίδων εμπεριέχει την ολοκλήρωση διαδικασιών και τις σχετικές δραστηριότητες και τους σχετικούς παράγοντες (Håkansson & Jahre 2004). Υπάρχουν τρεις οπτικές σε μία εφοδιαστική αλυσίδα. Η πρώτη περιγράφει ολόκληρη τη βιομηχανία ως μία εφοδιαστική αλυσίδα και προτείνει την πλήρη ολοκλήρωση των δραστηριοτήτων ((Akintoye et al. 2000; Proverbs & Holt 2000). Η δεύτερη εστιάζει σε συγκεκριμένες σχέσεις που υπάρχουν στη βιομηχανία (π.χ. κατασκευαστές-έμποροι) (London et al. 1998; Agapiou et al. 1998; Dainty, Briscoe, et al. 2001). Η τρίτη αντιμετωπίζει τη βιομηχανία ως ένα σύνολο διάφορων αλυσίδων, οι οποίες πρέπει να έχουν διαφορετική διαχείριση (Voordijk et al. 2000). Η οπτική της εφοδιαστικής αλυσίδας εξαρτάται από τη σκοπιά από την οποία παρατηρείται. Ο Eccles (1981) παρατηρεί την κατασκευαστική βιομηχανία μέσα από τη σκοπιά της «οιονεί» εταιρείας (quasi-firm), μια μορφή ενδιάμεση της αγοράς και της ιεραρχίας η οποία θεωρεί ότι οι υπεργολαβίες (subcontracting) αναπτύσσουν ένα σύνολο σταθερών σχέσεων ανάμεσα στον ανάδοχο και τους εξειδικευμένους υπεργολάβους, οδηγώντας σε μια μορφή σχεσιακών συμβάσεων. Οι Isatto και Formoso (2011) τείνουν να προτιμήσουν την οπτική της σκοπιάς Γλώσσα/Δράση (Language/Action Perspective), η οποία εξηγεί, πώς οι διαχειριστικές διαδικασίες μεταξύ εταιρειών συντονίζονται ακόμη και όταν υπάρχει ελάχιστος έλεγχος στην αλληλουχία και το περιεχόμενο των δραστηριοτήτων. Οι Crowston (1991) και Crowston και Osborn (1998) κατέληξαν η Θεωρία κόστους συναλλαγών (Transaction Cost Theory) δεν μπορεί να εφαρμοστεί στο συγκεκριμένο χώρο, καθώς αυτή υποθέτει ότι δεν υπάρχει διαμάχη ανάμεσα στους διάφορους παράγοντες και στους στόχους αυτών. Η θεωρία αυτή ασκεί κριτική στην εστίαση στα κόστη συναλλαγών αυτών καθ' αυτών χωρίς να λαμβάνει υπόψη το κόστος συντονισμού (Winch 2006). Η Θεωρία Συντονισμού (Theory of Coordination) εφαρμόζεται στο συντονισμό μεταξύ εταιρειών και σχετίζεται με το σκοπό κάθε εφοδιαστικής αλυσίδας στο πλαίσιο παροχής αξίας στον πελάτη μέσα από την ανάλυση της αποδόμησης και ανάθεσης εργασιών στους παράγοντες, των αλληλεξαρτήσεων που δημιουργούνται και του τρόπου διαχείρισής τους (Isatto & Formoso 2011). Μια σκοπιά που εστιάζει στις διαδικασίες αντιμετωπίζει μια εφοδιαστική αλυσίδα ως ένα σύστημα διαδικασιών και λειτουργιών (Vidalakis et al. 2011). Ο ακαδημαϊκός διάλογος είναι έντονος και σε πλήρη εξέλιξη, ωστόσο, αυτή η εργασία αναγνωρίζει την έλλειψη μιας διαδικασιοκεντρικής προσέγγισης στις σχέσεις των εφοδιαστικών αλυσίδων του κατασκευαστικού κλάδου.

Το 2001 οι Dainty et al. υποστήριξαν ότι η ανάπτυξη ενός λειτουργικού μοντέλου διαδικασιών το οποίο θα περιγράφει αποτελεσματικά την εφαρμογή της θεωρίας εφοδιαστικών αλυσίδων μέσα από την αλυσίδα αξίας είναι ακόμη ένας μακροπρόθεσμος στόχος, καθώς η βιβλιογραφία της εποχής ήταν πολύ φτωχή. Σήμερα η βιβλιογραφία έχει εμπλουτιστεί ιδιαίτερα σε σχέση με τις εφοδιαστικές αλυσίδες στον κατασκευαστικό κλάδο. Σκοπός της παρούσας έρευνας είναι η ανάλυση των διαδικασιών μιας χαρακτηριστικής εφοδιαστικής αλυσίδας κατασκευαστικού έργου. Το ερευνητικό ερώτημα που τίθεται είναι το παρακάτω: *Είναι δυνατή η δημιουργία ενός μοντέλου αναφοράς διαδικασιών για τις εφοδιαστικές αλυσίδες του κατασκευαστικού κλάδου, το οποίο μπορεί να υιοθετηθεί από οποιαδήποτε εταιρεία στον κατασκευαστικό κλάδο ανεξαρτήτως μεγέθους;* Ένα τέτοιο μοντέλο θα πρέπει να είναι καλά δομημένο, έτσι ώστε να ικανοποιούνται οι ανάγκες του τελικού καταναλωτή (Tommelein et al. 2003). Η διατριβή έχει τους παρακάτω σκοπούς: 1) τη σύνθεση των αναγκών και βέλτιστων πρακτικών των μικρομεσαίων και μεγάλων εταιρειών που δραστηριοποιούνται στον κατασκευαστικό κλάδο, 2) την ανάλυση των διαθέσιμων υπομοντέλων στη βιβλιογραφία, και 3) τη δημιουργία συνολικού μοντέλου αναφοράς για όλες τις εταιρείες του κατασκευαστικού κλάδου. Η έρευνα περιορίζεται στην ανάλυση της διαχείρισης εφοδιαστικών αλυσίδων από τη σκοπιά του ανάδοχου ενός έργου. Αυτό σημαίνει ότι οι δραστηριότητες των πελατών και των προμηθευτών αντιμετωπίζονται ως «μαύρο κουτί» και οι συναλλαγές μεταξύ των διαφόρων μερών δεν αναλύονται από τη σκοπιά του πελάτη ή του προμηθευτή. Επιπλέον, η ανάλυση των διαδικασιών σε πολύ χαμηλό επίπεδο γενίκευσης δεν αποτελεί σκοπό αυτής της εργασίας, καθώς μια τέτοια ανάλυση δημιουργεί τον κίνδυνο απώλειας της καθολικότητας του προτεινόμενου μοντέλου αναφοράς. Η αναγνώριση των διαδικασιών διαχείρισης της εφοδιαστικής αλυσίδας στον κατασκευαστικό κλάδο είναι μια εργασία πολύ απαιτητική. Για το λόγο αυτό, η ανάπτυξη άλλων οπτικών, όπως η οπτική κινδύνων ή η οπτική αποφάσεων δεν αποτελούν σκοπό αυτής της εργασίας, όπως επίσης δεν θα εξεταστούν διαδικασίες που περιγράφουν οριζόντιες συναλλαγές του αναδόχου. Τέλος, διαδικασίες και συναλλαγές, οι οποίες εκτελούνται εκτός του πλαισίου του άμεσου πελάτη ή προμηθευτή του αναδόχου δεν αποτελούν αντικείμενο έρευνας, καθώς μπορούν να περιγραφούν από υφιστάμενα μοντέλα αναφοράς.

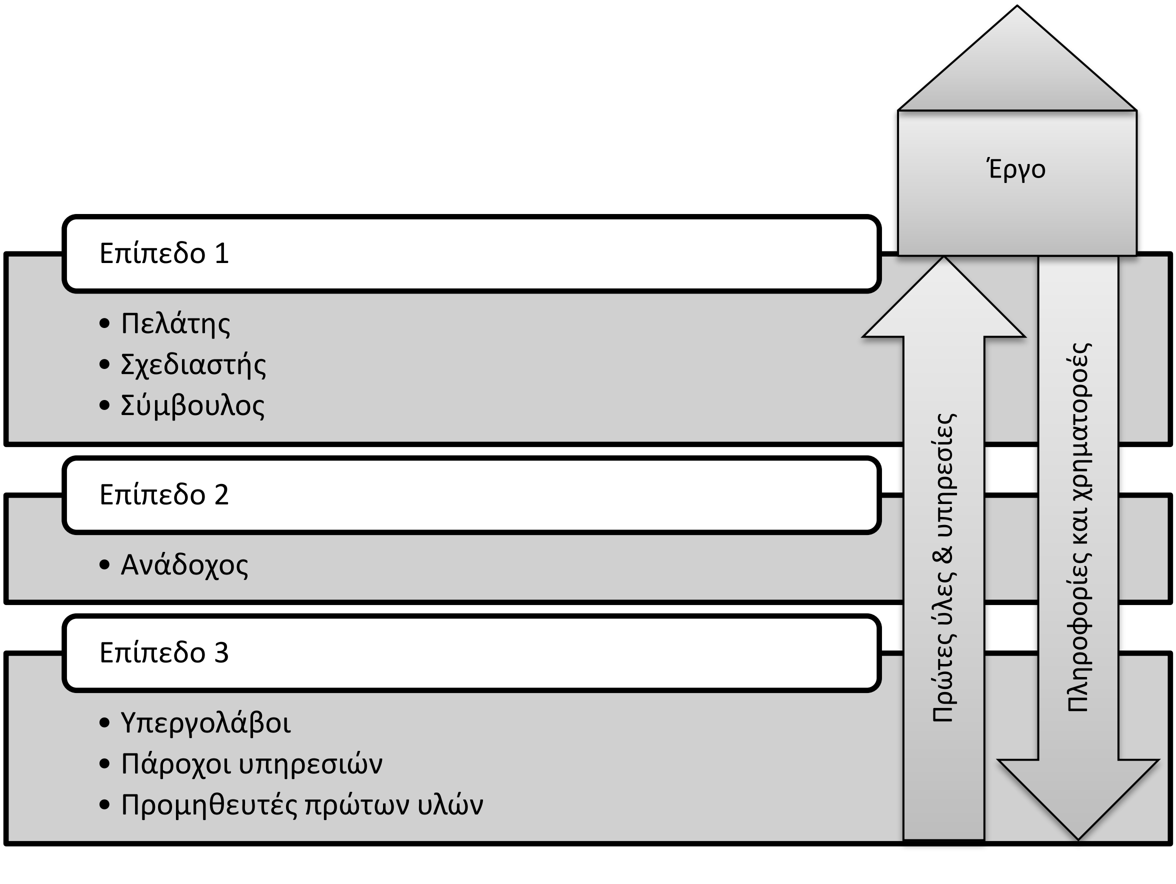
Η έρευνα που ακολουθεί δομείται ως εξής. Στο κεφάλαιο 2 πραγματοποιείται μια σύντομη βιβλιογραφική επισκόπηση της θεωρίας διαχείρισης εφοδιαστικών αλυσίδων στον κατασκευαστικό κλάδο. Στο κεφάλαιο 3 περιγράφεται η μεθοδολογική προσέγγιση που ακολουθήθηκε σε αυτή τη διατριβή και περιγράφεται το γενικό μοντέλο αναφοράς, στο οποίο βασίζεται το μοντέλο που παρουσιάζεται στο κεφάλαιο 4. Το κεφάλαιο 4 περιγράφει τις προσαρμογές που πραγματοποιήθηκαν στο γενικό μοντέλο αναφοράς και αναλύει το προτεινόμενο μοντέλο αναφοράς για τον κατασκευαστικό κλάδο. Το κεφάλαιο 5 περιέχει τη συζήτηση των αποτελεσμάτων της παρούσας έρευνας. Η διατριβή κλείνει με το κεφάλαιο 6, όπου παρουσιάζονται τα συμπεράσματα, οι περιορισμοί και προτάσεις για μελλοντική έρευνα.

2. Βιβλιογραφική επισκόπηση

Είναι κοινά αποδεκτό ότι δεν υπάρχουν δύο πανομοιότυπα κατασκευαστικά έργα. Κάθε έργο είναι μοναδικό από άποψη τεχνική, οικονομική και κοινωνικοπολιτική (Segerstedt & Olofsson 2010). Τα χαρακτηριστικά της κατασκευαστικής βιομηχανίας, όπως τα εξειδικευμένα συστήματα παραγωγής, η επιρροή του πελάτη, ο κατακερματισμός της αγοράς, το πλήθος των ενδιαφερόμενων μερών, το είδος των ενδιαφερόμενων μερών, οι σχέσεις αγοραστών-προμηθευτών, οι προσωρινές παράμετροι και η αντίσταση στην αλλαγή έχουν μεγάλη επίπτωση στην εφαρμογή καινοτόμων θεωριών, όπως είναι η Θεωρία της διαχείρισης εφοδιαστικών αλυσίδων (Aloini et al. 2012b). Παρά το γεγονός ότι τα κατασκευαστικά έργα έχουν κοινά χαρακτηριστικά σε σχέση με τα στάδιά τους και τις δομές τους, ο τρόπος προμήθειάς τους συχνά εξαρτάται από το μέγεθος, το εύρος, την αξία, την πολυπλοκότητα και την εξειδίκευσή τους (Adetola et al. 2011). Μία από τις παραμέτρους που επηρεάζουν τα αποτελέσματα ενός έργου είναι η εφοδιαστική του αλυσίδα. Ελλείψεις σε έμπειρους τεχνίτες, υλικά, διαταραχές που οφείλονται σε απρόβλεπτα ατυχήματα ή ακραία καιρικά φαινόμενα, αποτυχία εκπλήρωσης οικονομικών αναγκών, χρεοκοπίες, οικονομική διάσωση, ή άλλοι παράγοντες μπορούν να επηρεάσουν την εφοδιαστική αλυσίδα ενός έργου είτε σε μικρό βαθμό προκαλώντας καθυστερήσεις μερικών ημερών, είτε σε μεγαλύτερο βαθμό οδηγώντας σε μεγάλες αλλαγές στον προγραμματισμό του έργου, ακόμη και στην ακύρωση του έργου.

Σύμφωνα με τον Winch (2003) υπάρχουν τρεις κατηγορίες έργων: ιδιωτική κατοικία (η μόνη κατηγορία έργων, στην οποία ο ανάδοχος συναναστρέφεται με τον τελικό καταναλωτή), δόμηση (ικανοποίηση των αναγκών πελατών σε μία ποικιλία υποδομών χωρίς ιδιαίτερες τεχνικές απαιτήσεις, π.χ. δημόσιες κατοικίες) και, τέλος, μεγάλα έργα (ανάπτυξη υποδομών, κτίρια υψηλών προδιαγραφών, όπως για παράδειγμα νοσοκομεία και πολυώροφα γραφεία). Η επιλογή του τρόπου προμήθειας επηρεάζεται κατά κύριο λόγο από το υπάρχον οικονομικό κλίμα (Wolstenholme 2009), αλλά οι πελάτες του κατασκευαστικού κλάδου, οι ανάδοχοι και οι προμηθευτές είναι ικανοί να εξασφαλίσουν επιχειρηματικές ευκαιρίες μέσα από ένα ευρύ φάσμα στρατηγικών προμήθειας (Tennant & Fernie 2012). Οι σχέσεις στις εφοδιαστικές αλυσίδες της κατασκευαστικής βιομηχανίας είναι ποικίλες και μεταβάλλονται από οργανισμό σε οργανισμό, από έργο σε έργο ή ακόμη και ανάμεσα στα μέρη μίας συγκεκριμένης εφοδιαστικής αλυσίδας (Meng et al. 2011). Οι σχέσεις αγοραστών-προμηθευτών σε ένα παραδοσιακό περιβάλλον μπορούν να χαρακτηριστούν ως τυπικές σχέσεις συναλλαγής, στις οποίες σύμφωνα με τον Bensaou (1999) η ανταλλαγή πληροφοριών ανάμεσα σε δύο εταιρείες γίνεται κυρίως στο στάδιο της υποβολής προσφορών και της διαπραγμάτευσης των συμβάσεων. Παρά τον τοπικό περιορισμό των κατασκευαστικών αγορών, αυτές παρουσιάζουν υψηλό κατακερματισμό με πολλές μικρομεσαίες εταιρείες (Briscoe & Dainty 2005), οι οποίες εκτελούν μοναδικές δραστηριότητες (Ribeiro & Lopes 2001). Το πολύ υψηλό ποσοστό μικρομεσαίων εταιρειών στη βιομηχανία των κατασκευών σημαίνει ότι αυτές κατά πάσα πιθανότητα θα αντιπροσωπεύουν την πλειονότητα των εταιρειών που εμπλέκονται σε ένα κατασκευαστικό έργο. Το μικρό μέγεθος και ο μεγάλος αριθμός των μικρομεσαίων εταιρειών απαιτεί από τον ανάδοχο να συντονίσει τις εργασίες τους, έτσι ώστε να επιτευχθεί η εστίαση και η ολοκλήρωση των εμπλεκόμενων μερών (Akintan & Morledge 2013). Ένα πρόβλημα που αντιμετωπίζει η κατασκευαστική βιομηχανία είναι η τάση των αναδόχων να εστιάζουν αποκλειστικά στις ανάγκες των πελατών τους (Saad et al. 2002) και να παραμελούν τις σχέσεις τους με τους προμηθευτές τους.

Το σύστημα αξίας στον κατασκευαστικό κλάδο έχει μία κατακόρυφη και μία οριζόντια διάσταση (Campagnac et al. 2000). Στην κατακόρυφη διάσταση, την οποία ο Winch (2001) ονομάζει αλυσίδα έργου, οι διάφοροι παράγοντες έχουν άμεσες συμβάσεις με τον πελάτη. Στην οριζόντια διάσταση κάθε παράγοντας εκπληρώνει τις υποχρεώσεις του απέναντι στον πελάτη είτε μέσω μιας εργασιακής σχέσης είτε μέσω υπεργολαβίας στην εφοδιαστική αλυσίδα (Winch 2001). Οι Cox και Thompson (1998), όπως παρατίθενται από τους Ribeiro και Lopes (2001), ορίζουν την εφοδιαστική αλυσίδα των κατασκευών ως εξής: «μία εφοδιαστική αλυσίδα στον κατασκευαστικό κλάδο μπορεί να θεωρηθεί ως μία διαδικασία μιας σειράς δραστηριοτήτων που μετατρέπουν τις πρώτες ύλες σε τελικό προϊόν (π.χ. δρόμους ή κτίρια) και υπηρεσίες (π.χ. σχεδιασμός ή κοστολόγηση) προς χρήση από έναν πελάτη ανεξάρτητα από τα όρια ενός οργανισμού». Οι εφοδιαστικές αλυσίδες στον κλάδο των κατασκευών έχουν τρία κύρια χαρακτηριστικά: είναι συγκλίνουσες (πολλά μέρη και πολλές ροές που κινούνται ταυτόχρονα σε ένα αντικείμενο), είναι προσωρινές (έργα που στήνονται για ένα μόνο αντικείμενο) και ικανοποιούν παραγωγή κατά παραγγελία (υψηλό επίπεδο παραμετροποίησης) (Vrijhoef & Koskela 2000). Σύμφωνα με τους Arbulu et al. (2003) οι εφοδιαστικές αλυσίδες στον κλάδο των κατασκευών πρέπει να είναι καλοσχεδιασμένα δίκτυα αλληλένδετων διαδικασιών που έχουν σχεδιαστεί να ικανοποιούν τις ανάγκες του τελικού καταναλωτή. Σε μία εφοδιαστική αλυσίδα του κατασκευαστικού κλάδου ο πελάτης είναι ο τελικός καταναλωτής, ο ανάδοχος, ο σχεδιαστής και ο σύμβουλος διοίκησης έργου είναι προμηθευτές πρώτου επιπέδου, οι υπεργολάβοι είναι οι προμηθευτές δευτέρου επιπέδου και οι προμηθευτές τεχνιτών πρώτων υλών και εξοπλισμού είναι οι προμηθευτές τρίτου επιπέδου (Beach et al. 2005). Για τις ανάγκες αυτής της εργασίας υιοθετείται η οπτική της εφοδιαστικής αλυσίδας, όπως την περιγράφει ο Pryke (2009) (βλ. **Σχήμα 1** παρακάτω).



Σχήμα 1: Εφοδιαστική αλυσίδα κατασκευών (προσαρμογή από: Pryke 2009, σ.2)

Οι ανάδοχοι και οι διάφοροι σύμβουλοι αναπτύσσουν τη μεταξύ τους σχέση μέσω της απόφασης του πελάτη να αναθέσει στους συμβούλους τη λήψη των καθημερινών αποφάσεων εκ μέρους του και οι αλληλεπιδράσεις τους συνήθως περιγράφονται μέσα στη σύμβαση πελάτη-αναδόχου (Reve & Levitt 1984). Οι σύμβουλοι μηχανικοί, για παράδειγμα, είναι αυτοί που διοργανώνου και εκτελούν τους διαγωνισμούς εκ μέρους του πελάτη. Σε μια εφοδιαστική αλυσίδα οι σχέσεις ανάμεσα στα μέρη μπορεί να κυμαίνονται από ιεραρχικές μέχρι σχέσεις αγοράς, ανάλογα με τη δομή του κόστους συναλλαγών (Ronchi 2006). Η συχνότητα συναλλαγών μεταξύ του πελάτη και του αναδόχου είναι χαμηλή (Winch 2001). Σε αυτές τις συναλλαγές οι πελάτες επιθυμούν να μειώσουν τα κόστη και αυτό ωθεί τους αναδόχους στην ανάπτυξη υπεργολαβικών σχέσεων και άτυπων οργανωτικών συμφωνιών οι οποίες παρακινούνται από τον ανταγωνισμό στην τιμή και την αυτονομία κάθε επιχείρησης (Ronchi 2006).

Η θεωρία της διαχείρισης εφοδιαστικής αλυσίδας είναι νέα στον κλάδο των κατασκευών και προέρχεται από την παραγωγική βιομηχανία. Πρώτος την εισήγαγε στο χώρο ο Egan (1998) μέσα από την αναφορά που εκπόνησε για την κυβέρνηση του Η.Β. με τίτλο «rethinking construction» και έκτοτε η βιβλιογραφία έχει εμπλουτιστεί σημαντικά. Παρά την πλούσια βιβλιογραφία στον αντίστοιχο χώρο της παραγωγικής βιομηχανίας, τα αποτελέσματά της δεν είναι μπορούν να εφαρμοστούν χωρίς προσαρμογές στον κατασκευαστικό κλάδο. Μία από τις πιο χαρακτηριστικές ιδιαιτερότητες στις εφοδιαστικές αλυσίδες των κατασκευών είναι ότι ο τελικός καταναλωτής είναι συνήθως αποκομμένος από την παραγωγική διαδικασία, δηλαδή ο άμεσος πελάτης ενός ανάδοχου είναι συχνά κάποιος μεσίτης του τελικού καταναλωτή και ο τελευταίος δεν είναι γνωστός στον ανάδοχο (Segerstedt & Olofsson 2010).

Τα προβλήματα στην προμήθεια και τη ζήτηση του εργατικού δυναμικού στον κατασκευαστικό κλάδο είχαν εντοπιστεί από τη δεκαετία του 1980 (Blough 1983), όπως και οι αναποτελεσματικές ροές πληροφοριών. Παρόλα αυτά χρειάστηκε να περάσει μια δεκαετία για να δοθεί η απαραίτητη προσοχή σε αυτά τα ζητήματα. Ο Latham (1994) πρότεινε τη δημιουργία συμπράξεων στην αγορά των κατασκευών του Η.Β., ενώ ο Egan (1998) εισήγαγε τη θεωρία της εφοδιαστικής αλυσίδας στην ίδια αγορά, ανοίγοντας έτσι το δρόμο για την έρευνα στο συγκεκριμένο πεδίο. Συγκεκριμένα, ο Latham πρότεινε την υιοθέτηση της πρακτικής των συμπράξεων από τις κατασκευαστικές εταιρείες. Οι συμπράξεις είναι μία έννοια που περιγράφει το πλαίσιο, μέσα στο οποίο δύο εταιρείες μπορούν να καθιερώσουν κοινούς στόχους ανάμεσα στα μέλη μιας ομάδας με σκοπό αυτά να φτάσουν σε μια κοινά αποδεκτή διαδικασία επίλυσης διαφορών, ενώ ταυτόχρονα υιοθετούν αρχές συνεχούς βελτίωσης (Naoum 2003). Η έννοια αυτή έρχεται σε αντίθεση με την κλασσική πρακτική των υπεργολαβιών, στις οποίες ένας προμηθευτής απλά εκτελεί ένα μέρος της εργασίας του αναδόχου σε ένα έργο (Arditi & Chotibhongs 2005). Η υιοθέτηση συμπράξεων πρέπει να προωθεί την εμπιστοσύνη, τη συνεργασία και το ομαδικό πνεύμα, έτσι ώστε να εγγυάται την εστίαση των μερών στους στόχους του έργου. Αποτελεί έναν τρόπο διοίκησης που στοχεύει στην ευθυγράμμιση των οργανισμών, έτσι ώστε αυτοί να επιτύχουν μια κοινή αποστολή, ένα κοινό όραμα, να βελτιώσουν την ασφάλεια εργασίας, να δημιουργήσουν ποιοτικές ομάδες εργασίας, να καρπωθούν οικονομικά οφέλη, να βελτιώσουν τις σχέσεις συνεργασίας και να αποφύγουν δικαστικές διαμάχες. Τα πλεονεκτήματα από την υιοθέτηση συμπράξεων δεν είναι εμφανή στους ποσοτικούς παράγοντες (π.χ. οικονομικά δεδομένα), αλλά επηρεάζουν πλήθος ποιοτικών παραγόντων συμπεριλαμβανομένης της βελτιωμένης ομαδικής εργασίας, της αναγνώρισης κοινών στόχων, της μείωσης των κινδύνων και της αποδοτικότερης επίλυσης προβλημάτων (Burtonshaw-Gunn & Ritchie 2004). Η επιτυχία των συμπράξεων εξαρτάται από παράγοντες, όπως η επικοινωνία, η ομαδική εργασία, η κατανόηση των αναγκών των άλλων μερών, η εμπιστοσύνη και η ειλικρίνεια, ο καθορισμός και η κοινοποίηση μιας στρατηγικής αποφυγής συγκρούσεων, η θέληση για διαμοιρασμό πόρων, ο σαφής ορισμός των υποχρεώσεων, η δέσμευση για μία win-win φιλοσοφία, η συχνή παρακολούθηση των διαδικασιών και η εμπλοκή των εταίρων από το αρχικό στάδιο της διαδικασίας (Eriksson 2010; Chan et al. 2003). Οι Burtonshaw-Gunn και Ritchie (2004) περιγράφουν τρεις ομάδες εμποδίων στην προσπάθεια υιοθέτησης της πρακτικής των συμπράξεων: εταιρική κουλτούρα, παραδοσιακοί ρόλοι πελάτη-αναδόχου και απαιτούμενος χρόνος για την ανάπτυξη των απαραίτητων σχέσεων. Οι Chan et al. (2004) προσθέτουν την έλλειψη αφοσίωσης και υποστήριξης από τα υψηλόβαθμα στελέχη. Τέλος, ο Meng (2010) υπογραμμίζει ότι αυτοί οι παράγοντες οδηγούν, επίσης, και σε εχθρικές σχέσεις.

Παρά τα εμπόδια που εμφανίζονται στην εφαρμογή των συμπράξεων, ορισμένα μέλη της βιομηχανίας έχουν κινηθεί προς την υιοθέτηση σχέσεων, οι οποίες καθοδηγούνται από τις αρχές της θεωρίας διαχείρισης εφοδιαστικών αλυσίδων με σκοπό να βελτιώσουν την ποιότητα και αποτελεσματικότητά τους βασιζόμενες στις προτάσεις του Egan (1998). Αυτή η τάση παρατηρείται κυρίως από γνώστες πελάτες του ιδιωτικού τομέα που είχαν υιοθετήσει την πρακτική των συμπράξεων στις αρχές της δεκαετίας του 1990. Οι πελάτες αυτοί προσπαθούν να αυξήσουν το επίπεδο συνεργασίας ανάμεσα στους συμβούλους και στους αναδόχους και ταυτόχρονα να επεκτείνουν αυτή την προσέγγιση κατά μήκος της εφοδιαστικής αλυσίδας, έτσι ώστε να συμπεριληφθούν οι σημαντικοί υπεργολάβοι και οι προμηθευτές. Αυτή η τάση έχει παρατηρηθεί και από μερικούς πελάτες του δημόσιου τομέα (Saad et al. 2002). Παρά τις προαναφερθείσες προσπάθειες, πρέπει να τονιστεί ότι η αντίστοιχη έρευνα που έχει πραγματοποιηθεί για την παραγωγική βιομηχανία δεν μπορεί να εφαρμοστεί πιστά στην κατασκευαστική βιομηχανία εξαιτίας της φύσης της παραγωγής μέσα από έργα (O'Brien 1999). Στη βιβλιογραφία, σε αντίθεση με τη θεωρία των εφοδιαστικών αλυσίδων για την παραγωγική βιομηχανία, το ερευνητικό πεδίο που αφορά σε εφοδιαστικές αλυσίδες στις κατασκευές είναι ακόμη στην απαρχή του και υπάρχουν ακόμη ακαδημαϊκοί στο χώρο των κατασκευών που υποστηρίζουν ότι η συγκεκριμένη θεωρία δεν μπορεί να εφαρμοστεί στις κατασκευές (π.χ. Winch 2003, Green et al. 2005, Fearne & Fowler 2006). Όπως και στην περίπτωση της γενικότερης θεωρίας διαχείρισης εφοδιαστικών αλυσίδων, έτσι και οι ακαδημαϊκοί του χώρου δεν έχουν συμφωνήσει σε έναν κοινά αποδεκτό ορισμό για τις εφοδιαστικές αλυσίδες των κατασκευών. Μερικοί από τους ορισμούς αυτούς ακολουθούν παρακάτω.

- Οι Persson et al. (2010) ορίζουν τη διαχείριση της εφοδιαστικής αλυσίδας ως «το έργο της ολοκλήρωσης οργανωτικών μονάδων κατά μήκος μιας εφοδιαστικής αλυσίδας, συμπεριλαμβανομένων του εργοταξίου και των υπεργολάβων, και του συντονισμού των οικονομικών ροών, καθώς και των ροών πρώτων υλών και πληροφοριών με το πλάνο του εργοταξίου με στόχο την επίτευξη της ικανοποίησης των απαιτήσεων του τελικού πελάτη.»
- Οι Aloini et al. (2012b) αναφέρονται στο «συντονισμό και την ολοκλήρωση κύριων κατασκευαστικών εργασιών, τόσο διαδικασιών όσο και παραγόντων που εμπλέκονται στην κατασκευαστική εφοδιαστική αλυσίδα, επεκτείνοντας παραδοσιακά ενδο-εταιρικές δραστηριότητες σε μια φιλοσοφία διαχείρισης, φέρνοντας σε επαφή εταίρους που έχουν κοινούς στόχους βελτιστοποίησης και απόδοσης, καθιερώνοντας μακροπρόθεσμες, win-win και συνεργατικές σχέσεις μεταξύ των ενδιαφερόμενων μερών στο πλαίσιο μιας συστημικής προσέγγισης.»

- Οι Cooper και Rousseau (1999), όπως τους παραθέτουν οι Voordijk και Vrijhoef (2003) υποστηρίζουν ότι «η εφοδιαστική αλυσίδα των κατασκευών μπορεί να ερμηνευθεί ως μια 'εκτεταμένη επιχείρηση', στην οποία όλα τα μέρη (σχεδιαστής, αρχιτέκτονας, μηχανικός, ανάδοχος, υπεργολάβοι, προμηθευτές) λειτουργούν ουσιαστικά ως 'επιχειρησιακές μονάδες' αναπαριστώντας τις 'εταιρικές λειτουργίες' (μάρκετινγκ, σχεδιασμός, μηχανική, παραγωγή μερών, προμήθεια, συναρμολόγηση, παράδοση) ενός 'εργοστασίου χωρίς τοίχους', που δρα ως ένα συνεργατικό δίκτυο οργανωτικών ομάδων, ανεξάρτητα από την τοποθεσία και τον ιδιοκτήτη αυτών.»

Η διαχείριση εφοδιαστικών αλυσίδων στις κατασκευές προσφέρει νέες προοπτικές για τη μείωση του κόστους και την αύξηση της αξιοπιστίας και ταχύτητας της κατασκευής (O'Brien 1999). Ωστόσο, η εφαρμογή της θεωρίας στη βιομηχανία των κατασκευών χαρακτηρίζεται ως διάσπαρτη και μερική (Gadde & Dubois 2010). Τα οφέλη από την υιοθέτηση της συγκεκριμένης θεωρίας, όπως τα κατέγραψαν οι Papadopoulos et al. (2016) περιλαμβάνουν: μειωμένα πραγματικά κόστη, διατήρηση περιθωρίων, κίνητρα για εξάλειψη της σπατάλης στη διαδικασία της κατασκευής, ανταγωνιστικά πλεονεκτήματα, μεγαλύτερη βεβαιότητα επί του τελικού κόστους, παράδοση καλύτερης υποκείμενης αξίας στον πελάτη, έγκαιρη παράδοση, βελτίωση παραγωγικότητας, βελτίωση αξίας παραγωγής, πρόσθετη επαναλαμβανόμενη συνεργασία με καίριους πελάτες, μεγαλύτερη εμπιστοσύνη στον μακροχρόνιο σχεδιασμό και βελτιωμένες σχέσεις μεταξύ των μερών ενός έργου.

Την επόμενη δεκαετία, όπως και σε άλλες βιομηχανίες, έτσι και στη κατασκευαστική, ο ανταγωνισμός αναμένεται να είναι ανάμεσα σε εφοδιαστικές αλυσίδες και όχι ανάμεσα σε ανεξάρτητες εταιρείες του κλάδου (Sharma 2012). Οι Pan et al. (2011) τονίζουν ότι χωρίς καλή διαχείριση εφοδιαστικών αλυσίδων κατά τη διοίκηση των έργων θα υπάρχουν επιπλέον κόστη, αναποτελεσματικές ροές πληροφοριών, και αναποτελεσματική επικοινωνία ανάμεσα στα μέρη του έργου. Η κεντρική διαχείριση των εφοδιαστικών αλυσίδων, εκτός από τη μείωση του κόστους, ενισχύει τη μεταφορά της τεχνογνωσίας και τη συστηματική παροχή ανάδρασης πάνω σε θέματα προγραμματισμού, σχεδιασμού, κατασκευής και συντήρησης και, εν τέλει, επικουρεί την μεγιστοποίηση της συνολικής αξίας της συνεργασίας (Voordijk & Vrijhoef 2003). Σε αντίθεση με τις σύγχρονες πρακτικές που τείνουν να ενισχύουν τον κατακερματισμό που μαστίζει τον κατασκευαστικό κλάδο, η θεωρία της διαχείρισης εφοδιαστικών αλυσίδων υπόσχεται μια βάση εφαρμοσμένης μηχανικής για το σχεδιασμό, τον προγραμματισμό και τη διοίκηση των κατασκευαστικών έργων μέσω μιας συνεργατικής πρακτικής (O'Brien 1999). Ανάλογα με το βαθμό εστίασης της διοίκησης στην εφοδιαστική αλυσίδα, το εργοτάξια ή και τα δύο, η θεωρία διαχείρισης εφοδιαστικών αλυσίδων έχει τέσσερα κύρια σημεία εστίασης στις κατασκευές σύμφωνα με τους Vrijhoef και Koskela (2000): εστίαση στον αντίκτυπο της εφοδιαστικής αλυσίδας στις δραστηριότητες του εργοταξίου, εστίαση στην εφοδιαστική αλυσίδα με στόχο τη μείωση της υλικοτεχνικής υποστήριξης, των χρόνων αναμονής και του κόστους αποθεματοποίησης, εστίαση στη μετακύληση δραστηριοτήτων από το εργοτάξιο σε προηγούμενα στάδια της εφοδιαστικής αλυσίδας, και εστίαση στην ενοποιημένη διαχείριση και βελτίωση της εφοδιαστικής αλυσίδας και των εργασιών κατασκευής. Τα σημεία εστίασης αυτά δεν είναι αμοιβαία αποκλειόμενα και συχνά χρησιμοποιούνται ταυτόχρονα (Papadopoulos et al. 2016).

Αρκετές εταιρείες του κλάδου των κατασκευών έχουν προσπαθήσει να υιοθετήσουν πρακτικές διαχείρισης εφοδιαστικών αλυσίδων αλλά χωρίς επιτυχία. Αναλύοντας τη βιβλιογραφία, μπορεί κανείς να εντοπίσει αρκετά αίτια για αυτές τις αποτυχίες. Οι Briscoe και Dainty (2005) εντόπισαν έξι βασικούς λόγους για τους οποίους αποτυγχάνει η υιοθέτηση των συγκεκριμένων πρακτικών: έλλειψη εμπιστοσύνης ανάμεσα στα εμπλεκόμενα μέρη στα διάφορα στάδια της εφοδιαστικής αλυσίδας, έλλειψη συστημάτων σε όλα τα επίπεδα της εφοδιαστικής αλυσίδας η οποία οδηγεί σε αδυναμία συντονισμού συστημάτων και διαδικασιών, συγχρονισμός οδηγούμενος κυρίως από τεχνικές διοίκησης έργων και ευθυγράμμιση πληροφοριακών συστημάτων, έννομα συμφέροντα, πολυπλοκότητα κάθε έργου σε σχέση με τα εμπλεκόμενα μέρη, και, στις περισσότερες περιπτώσεις, έλλειψη διάθεσης για ανάπτυξη συνεργατικών σχέσεων από το νωρίτερο δυνατό σημείο του έργου. Άλλοι συγγραφείς χαρακτηρίζουν την έλλειψη κατανόησης βασικών εννοιών της θεωρίας διαχείρισης εφοδιαστικών αλυσίδων ως το μεγαλύτερο εμπόδιο στην εφαρμογή των πρακτικών αυτών (Fernie & Thorpe 2007; Saad et al. 2002). Οι Fernie και Thorpe (2007) πιστεύουν ότι η πλειάδα των διαθέσιμων ορισμών της διαχείρισης εφοδιαστικής αλυσίδας συμβάλει στην αδυναμία υιοθέτησής των πρακτικών της από τις κατασκευαστικές εταιρείες. Οι Saad et al. (2002) υποστηρίζουν ότι οι κατασκευαστικές εταιρείες δεν έχουν συνειδητοποιήσει την ανάγκη για εξωτερική υποστήριξη στις προσπάθειες που καταβάλουν για υιοθέτηση αυτών των πρακτικών και για το λόγο αυτό οι πιθανότητες επιτυχίας τους είναι περιορισμένες. Η ασυνεχής ζήτηση και ο μεταβαλλόμενος φόρτος εργασίας σχετίζονται επίσης με τις προαναφερθείσες αποτυχίες (Segerstedt & Olofsson 2010). Επιπλέον, ο εγκλωβισμός σε αυστηρές πρακτικές συμπράξεων δεν επιτρέπει την πλήρη εκμετάλλευση των δυνατοτήτων που προσφέρει οι πρακτικές διαχείρισης εφοδιαστικής αλυσίδας (Briscoe & Dainty 2005; Saad et al. 2002; Fernie & Thorpe 2007).

Ωστόσο, οι εταιρείες που υιοθετούν πρακτικές διαχείρισης εφοδιαστικής αλυσίδας (κυρίως οι ανάδοχοι και οι υπεργολάβοι τους) πρέπει να αντιμετωπίσουν διαχειριστικά, οργανωτικά, σχεσιακά και τεχνολογικά ζητήματα που απαιτούν προσεκτική διαχείριση έτσι ώστε να είναι αποδοτική η εφαρμογή των αρχών, των μοντέλων και των τεχνικών διαχείρισης εφοδιαστικής αλυσίδας και να υπερκεραστούν τα εμπόδια στην εφαρμογή της διαχείρισης εφοδιαστικών αλυσίδων στο κλάδο των κατασκευών (Palaneeswaran et al. 2003). Ένα σημαντικό ζήτημα που αφορά στις διευρυμένες επιχειρήσεις και στις εικονικές εταιρείες είναι ο διαχωρισμός, η κατανομή, και ο συντονισμός των λειτουργιών, των εξειδικευμένων εργασιών και των εταίρων, όπως τονίζουν οι Voordijk και Vrijhoef (2003). Ο μεγάλος αριθμός μικρών και μικρομεσαίων εταιρειών στον κλάδο εντείνει το συγκεκριμένο πρόβλημα. Είναι απαραίτητη η στενή συνεργασία, ο συντονισμός και η επικοινωνία σε ένα δίκτυο εταιρειών στο οποίο, όπως προτείνουν οι Burtonshaw-Gunn και Ritchie (2004), η επιτυχημένη σχέση ανάμεσα στον πελάτη και τον ανάδοχο μπορεί να οδηγήσει στην αποτελεσματικότητα και αποδοτικότητα όλων των διαστάσεων της εφοδιαστικής αλυσίδας (οριζόντια και κάθετα).

Οι σημαντικότεροι παράγοντες σε μία σχέση είναι η επικοινωνία, η εμπιστοσύνη και η συνεργασία. Η ανοιχτή και αποτελεσματική επικοινωνία διαφαίνεται μέσα από τη διαφάνεια, το διαμοιρασμό πληροφοριών και την εκπαίδευση (Palaneeswaran et al. 2003; Chen & Chen 2007). Οι Hsu et al. (2008) περιγράφουν το διαμοιρασμό πληροφοριών ως την ενοποίηση πληροφοριακών συστημάτων, συστημάτων λήψης αποφάσεων και των επιχειρησιακών διαδικασιών που χρησιμοποιούνται για την εκτέλεση αναζητήσεων πληροφοριών, τη διαχείριση επιχειρησιακών λειτουργιών, την παρακολούθηση λεπτομερειών και την εκτέλεση άλλων διεργασιών. Η επικοινωνία διευκολύνεται με τη χρήση τεχνολογιών πληροφορικής (Alshawi & Ingirige 2003; Benton & McHenry 2010). Η εμπιστοσύνη κατά τον Sako (1992 σύμφωνα με τον Meng (2010)) έχει τρεις τύπους: τη συμβατική εμπιστοσύνη, την εμπιστοσύνη στην ικανότητα να εκτελεστεί μια εργασία και την καλοπροαίρετη εμπιστοσύνη. Η εμπιστοσύνη μπορεί να οδηγήσει σε ευκολότερες διαπραγματεύσεις, λιγότερες συγκρούσεις και βελτιωμένη απόδοση στις σχέσεις ανταλλαγής (Hartmann & Caerteling 2010). Η εμπιστοσύνη επηρεάζει και επηρεάζεται από την εξειδίκευση των περιουσιακών στοιχείων, την αβεβαιότητα, τη συχνότητα των συναλλαγών, την πολυπλοκότητα των εργασιών και τη δυσκολία στη μέτρηση της απόδοσης (Poppo & Zenger 2002). Δυστυχώς, στο τεταμένο περιβάλλον των κατασκευών, η μέτρηση της απόδοσης έχει συνδεθεί με την καχυποψία ανάμεσα στα μέρη (Larson 1997). Τέλος, η συνεργασία ορίζεται από τους Simatupang et al. (2004) ως δύο ή περισσότερες ανεξάρτητες εταιρείες που εργάζονται από κοινού για την ευθυγράμμιση των διαδικασιών διαχείρισης εφοδιαστικής αλυσίδας ώστε να δημιουργήσουν αξία για τους τελικούς καταναλωτές και τους ενδιαφερόμενους με μεγαλύτερη επιτυχία από αυτή που θα είχαν αν εργάζονταν ανεξάρτητα. Σύμφωνα με τον Meng (2013), οι σχετικές με τη συνεργασία στην εφοδιαστική αλυσίδα τάσεις χαρακτηρίζονται από: ευρεία αναγνώριση της σημασίας που έχει η συνεργασία σε επίπεδο εφοδιαστικής αλυσίδας για την κατασκευαστική βιομηχανία, υποστήριξη από κυβερνήσεις (π.χ. Η.Β.), ευρεία αποδοχή της συνεργατικής εργασίας ως στρατηγική διοίκησης, και ανισορροπία στην ανάπτυξη των σχέσεων. Στην ουσία, η κύρια ιδέα στην οποία βασίζεται η συνεργασία είναι η ολοκλήρωση των διαδικασιών της εφοδιαστικής αλυσίδας με στόχο την παροχή βελτιωμένης αξίας για τον πελάτη (Bankvall et al. 2010). Η αποτελεσματική συνεργασία χαρακτηρίζεται από τις ακόλουθες διακριτές προοπτικές: από κοινού ευθύνη, ομάδα εστιασμένη στην εκτέλεση εργασιών, κοινές δομές και ικανότητες, και συνέργεια σε υψηλόβαθμο επίπεδο (Suprapto et al. 2015). Η συνεργασία είναι προαπαιτούμενο για την απομάκρυνση νομικών και οργανωτικών περιορισμών και την υποστήριξη αυξημένων επιπέδων καινοτομίας (Dulaimi et al. 2002). Οι Shelbourn et al. (2007) χαρακτήρισαν την ύπαρξη των παρακάτω παραμέτρων κρίσιμη για τη συνεργασία: σύνολο διαδικασιών κοινό για όλους τους εμπλεκόμενους, πρότυπα που υποστηρίζουν τη συνέργεια συστημάτων, διαδικασίες που προωθούν την εμπιστοσύνη ανάμεσα στους συνεργάτες, διαδικασίες που επιτρέπουν στους συμμετέχοντες να συμφωνήσουν σε ένα κοινό όραμα και κοινές προτεραιότητες για τη συνεργασία, διαδικασίες που επιτρέπουν στα στελέχη να δεσμεύουν συμμετέχοντες-κλειδί, εργαλεία που μετρούν τα οφέλη της συνεργασίας για την εταιρεία, συμφωνημένη και καλώς ορισμένη ορολογία, δείκτες για τη μέτρηση της απόδοσης της συνεργασίας, τυποποιημένες τεχνολογίες που υποστηρίζουν τις ανάγκες της συνεργασίας, και εργαλεία που αξιολογούν την αποδοτικότητα των τεχνικών συνεργατικής εργασίας για κάθε διαδικασία.

Η κατασκευαστική βιομηχανία μπορεί να ενισχύσει την οικονομική ανάπτυξη μιας χώρας χάρη στον πολλαπλασιαστικό χαρακτήρα των δραστηριοτήτων της (Akintoye & Skitmore 1994), αλλά δέχεται κριτική για την αναποτελεσματικότητα και την έλλειψη καινοτομίας που διακρίνει τις λειτουργίες της (Edum-Fotwe et al. 2004; Leblanc et al. 2013; Khanzode et al. 2006). Παρά το αυξανόμενο ενδιαφέρον των ερευνητών για το πεδίο των εφοδιαστικών αλυσίδων στον κλάδο των κατασκευών, μπορεί να παρατηρηθεί μια συγκεκριμένη τάση σε σχέση με τις δημοσιεύσεις. Αυτή η τάση αφορά στο διαχωρισμό της έρευνας, από τη μία πλευρά, στη διαχείριση της ροής προϊόντων και πληροφοριών από και προς το εργοτάξιο και, από την άλλη πλευρά, στη διαχείριση των υλικών και των πόρων εντός του εργοταξίου (Persson et al. 2010). Υπάρχει πρόοδος σε σχέση με την υιοθέτηση τεχνολογιών και εργαλείων, ωστόσο δεν έχει υπάρξει σημαντική βελτίωση της παραγωγικότητας στον κλάδο (Abdel-Wahab & Vogl 2011; Fulford & Standing 2014; van Lith et al. 2015). Οι Barker et al. (2000) και Love et al. (2004) εντόπισαν σαφές κενό στη βιβλιογραφία όσον αφορά στην ολιστική διαχείριση εφοδιαστικών αλυσίδων στα κατασκευαστικά έργα. Οι μέχρι στιγμής προσπάθειες υιοθέτησης της συγκεκριμένης πρακτικής βασίζονται σε λογικές ευέλικτης ή/και λιτής παραγωγής (Vidalakis et al. 2013). Οι Boes και Holmen (2003) υπογραμμίζουν ότι οι συγκεκριμένες πρακτικές στοχεύουν κυρίως στην αλλαγή των σχέσεων πελάτη-αναδόχου, αλλά μπορούν επίσης να αλλάξουν τη σχέση ανάμεσα στους αναδόχους και τους προμηθευτές τους, οι οποίοι μπορεί να είναι υπεύθυνοι για το σχεδιασμό και τη τεχνική μελέτη συγκεκριμένου μέρους του έργου. Σήμερα, η συνήθης πρακτική ακολουθεί συμπτωματική αντιμετώπιση των προβλημάτων της εκάστοτε εφοδιαστικής αλυσίδας παρά το γεγονός ότι έτσι δεν γεννάται επαναληψιμότητα, δεν ορίζει πιθανές εναλλακτικές και δράσεις, και δεν περιγράφει καθαρά τους διάφορους τομείς ευθύνης (Kovács 2016). Οι Vollman et al. (1998) (όπως παρατίθενται από τους Love et al. (2004)) προτείνουν ότι η διαχείριση εφοδιαστικών αλυσίδων στις κατασκευές πρέπει να αντιμετωπίζεται ως ενοποιημένο σύνολο πρακτικών οι οποίες στοχεύουν στη διαχείριση και στο συντονισμό ολόκληρης της εφοδιαστικής αλυσίδας από τις πρώτες ύλες μέχρι τους τελικούς καταναλωτές. Οι συνεργατικές πρωτοβουλίες (π.χ. (e.g. Latham 1994; Egan 1998; Egan 2002) και στρατηγικές (Robeiro & Love 2003; Love et al. 2004; MacLeamy 2012; Nag et al. 2014) οι οποίες έχουν αναπτυχθεί αναδεικνύουν τη θέληση του κλάδου να βελτιώσει τις σχέσεις και την απόδοση των εταιρειών (Anvuur & Kumaraswamy 2006).

Η έρευνα που διεξήχθη από τους Arbulu et al. (2002) έδειξε ότι οι εφοδιαστικές αλυσίδες των κατασκευών είναι διαθέσιμες για αποτύπωση με τη χρήση μοντέλων διαδικασιών. Σε γενικές γραμμές, η φύση των διαδικασιών που εκτελούνται στα πλαίσια μιας εφοδιαστικής αλυσίδας με δια-επιχειρησιακές δραστηριότητες, οι οποίες εμπλέκουν διάφορες εταιρείες, προσφέρεται για το σχεδιασμό, την ανάλυση, τον έλεγχο και την αξιολόγησή τους με ένα καλοσχεδιασμένο και δομημένο τρόπο (Panayiotou et al. 2010). Η αναδόμηση των διαδικασιών στις εφοδιαστικές αλυσίδες των κατασκευών θεωρείται η πλέον υποσχόμενη ευκαιρία του κλάδου να επιτύχει μείωση στα κόστη του (Lönngren et al. 2010). Τα μοντέλα διαδικασιών μπορούν να παρέχουν ολοκληρωμένη κατανόηση των διαδικασιών και να αναλύσουν και ολοκληρώσουν επιχειρήσεις μέσω των διαδικασιών τους (Aguilar-Savén 2004). Τα μοντέλα διαδικασιών τοποθετούνται στο προσκήνιο ως μέσο επίτευξης επιχειρησιακής διαλειτουργικότητας σε επίπεδο διαδικασιών και ευελιξίας σε δυναμικές εφοδιαστικές αλυσίδες (Ponis 2005). Ο ολοκληρωμένος συντονισμός όλων των διαδικασιών και λειτουργιών είναι προαπαιτούμενο για την επιτυχημένη διαχείριση των εφοδιαστικών αλυσίδων της κατασκευαστικής βιομηχανίας (Lönngren et al. 2010). Υπάρχει ξεκάθαρο κενό στη βιβλιογραφία σε αυτό το σημείο παρά το γεγονός ότι η χρήση του μοντέλου SCOR έχει αποδώσει πλεονεκτήματα σε ορισμένες περιπτώσεις (Persson et al. 2010). Η διατριβή αυτή στοχεύει να καλύψει το κενό της βιβλιογραφίας με τη δημιουργία ενός ολοκληρωμένου μοντέλου αναφοράς διαδικασιών το οποίο λαμβάνει υπόψη όλες τις ιδιαιτερότητες της κατασκευαστικής βιομηχανίας. Αυτή τη στιγμή, οι προσπάθειες που έχουν γίνει στην κατασκευαστική βιομηχανία για να υιοθετηθούν μοντέλα αναφοράς τα οποία αναπτύχθηκαν είτε από ακαδημαϊκούς είτε από κυβερνήσεις έχουν αποτύχει καθώς υπάρχει ανάγκη, πρώτον, να ενημερωθούν οι επαγγελματίες του χώρου για τα πλεονεκτήματα που προσφέρουν σε σχέση με την κατανόηση, τη συνοχή και την αποδοτικότητα των διαδικασιών και, δεύτερον, να εκπαιδευτούν στην εφαρμογή τους (Jones & Sharp 2007). Επιπροσθέτως, η χρήση γλωσσών περιγραφής διαδικασιών στον κατασκευαστικό κλάδο είναι κατακερματισμένη (Kovács 2016). Εν κατακλείδι, η διαχείριση εφοδιαστικών αλυσίδων δεν είναι επαρκώς διαδεδομένη ούτε υιοθετείται εξολοκλήρου από τις εταιρείες του κλάδου (Fernie & Tennant 2013; Arantes et al. 2015). Η διατριβή αυτή στοχεύει στην κάλυψη του κενού που εντοπίζεται στη βιβλιογραφία με τη δημιουργία ενός μοντέλου αναφοράς διαδικασιών το οποίο να είναι δομημένο έτσι ώστε να γίνεται κατανοητό τόσο από την ακαδημαϊκή κοινότητα όσο και από τους επαγγελματίες του κλάδου.

3. Μεθοδολογική προσέγγιση

Για να δημιουργηθεί ένα μοντέλο αναφοράς διαδικασιών απαιτείται μια στιβαρή μεθοδολογική προσέγγιση. Η μεθοδολογική προσέγγιση που ακολουθήθηκε σε αυτή την εργασία είναι μια εκτεταμένη έκδοση της μεθοδολογίας που περιγράφεται από τους Gayialis et al. (2013). Οι συγγραφείς είχαν ακολουθήσει μια προσέγγιση από την κορυφή προς τη βάση (top down) και από τη βάση προς την κορυφή (bottom up), η οποία κρίνεται κατάλληλη για την παρούσα έρευνα, καθώς συναντάται και στη βιβλιογραφία των κατασκευών. Οι Bouchlaghem et al. (2004) ακολούθησαν αυτή τη μέθοδο για να ορίσουν τη δομή των ροών των διαδικασιών κατά τα στάδια ανάπτυξης και κατασκευής ενός έργου. Σε πιο πρόσφατη έρευνα, οι Pan και Goodier (2012) ακολούθησαν την ίδια μέθοδο για να καταγράψουν σημαντικά θέματα που αφορούν επιχειρησιακά μοντέλα, διαδικασίες κατασκευών και τις σχέσεις μεταξύ τους στο πλαίσιο των προκατασκευασμένων μερών ενός κτιρίου.

Παρακάτω περιγράφονται έξι βήματα, τα οποία ακολουθήθηκαν στην παρούσα εργασία, εκ των οποίων τα πρώτα τέσσερα περιγράφηκαν από τους Gayialis et al. (2013) και τα δύο τελευταία αποτελούν προσθήκες για τις ανάγκες αυτής της εργασίας.

Βήμα 1: Μελέτη της βιβλιογραφίας σχετικά με τη διαχείριση εφοδιαστικών αλυσίδων στον κατασκευαστικό κλάδο

Σε αυτό το βήμα μελετήθηκαν οι σύγχρονες θεωρίες και πρακτικές στο χώρο της διαχείρισης εφοδιαστικών αλυσίδων στον κατασκευαστικό κλάδο. Οι ιδιαιτερότητες του κατασκευαστικού κλάδου, η θεωρία της διαχείρισης εφοδιαστικών αλυσίδων στον κατασκευαστικό κλάδο, υπάρχοντα γενικά και ειδικά μοντέλα αναφοράς διαδικασιών στον κατασκευαστικό κλάδο και καταγεγραμμένες διαδικασίες αποτέλεσαν αντικείμενο μελέτης. Καταγεγραμμένες πρακτικές, βέλτιστες πρακτικές και τάσεις στο χώρο της πληροφορικής ερευνήθηκαν επίσης. Αυτό το βήμα κατέληξε στην αναγνώριση των βασικών κατευθύνσεων και απαιτήσεων για το μοντέλο αναφοράς.

Βήμα 2: Μελέτη των μοντέλων αναφοράς εφοδιαστικών αλυσίδων

Σε αυτό το βήμα εφαρμόζεται η προσέγγιση από την κορυφή προς τη βάση (top down) μέσα από τη μελέτη υφιστάμενων μοντέλων αναφοράς για εφοδιαστικές αλυσίδες. Η προσαρμογή και παραμετροποίηση υφιστάμενων μοντέλων αναφοράς αποτέλεσε την αφετηρία για την ανάπτυξη του τελικού μοντέλου αναφοράς που παρουσιάζεται σε αυτήν την εργασία. Καθώς αυτή η έρευνα είναι συνδεδεμένη με το ερευνητικό πρόγραμμα «ΟΔΥΣΣΕΑΣ» (Ολιστική Διαχείριση της Μεταβλητότητας στις Σύγχρονες Εφοδιαστικές Αλυσίδες της Παγκοσμιοποιημένης Αγοράς) και το μοντέλο REMEDY που αναπτύχθηκε (Ponis et al. 2013; Gayialis et al. 2013), η δομή και τα βασικά χαρακτηριστικά του μοντέλου διατηρήθηκαν.

Βήμα 3: Επισκόπηση μεθόδων και εργαλείων μοντελοποίησης επιχειρησιακών διαδικασιών

Η ανάπτυξη του γενικού μοντέλου αναφοράς REMEDY βασίστηκε σε ένα σύνολο μεθόδων και εργαλείων μοντελοποίησης επιχειρησιακών διαδικασιών τα οποία επιλέχθηκαν μετά από εκτεταμένη ανάλυση της βιβλιογραφίας και της αναφοράς. Η αρχιτεκτονική μοντελοποίησης που χρησιμοποιήθηκε, βασίστηκε στα παρακάτω κριτήρια:

- Απεικόνιση και ολοκλήρωση των διαφορετικών οπτικών μιας εφοδιαστικής αλυσίδας, όπως η οπτική οργάνωσης, πληροφοριών, αποφάσεων, κινδύνων και γνώσης.

- Εφαρμογή σε διάφορους τύπους επιχειρησιακών διαδικασιών: δημόσιες, ιδιωτικές και συνεργατικές επιχειρησιακές διαδικασίες.
- Ανάπτυξη επαναχρησιμοποιούμενων μοντέλων με τη μορφή ενός μοντέλου αναφοράς.
- Ευκολία χρήσης και κατανόησης από το χρήστη.
- Ύπαρξη ενός εργαλείου λογισμικού, το οποίο θα υποστηρίζει τη χρήση διαφόρων μεθόδων με ολοκληρωμένο τρόπο.

Το γενικό μοντέλο αναφοράς REMEDY χρησιμοποίησε την αρχιτεκτονική ARIS (Scheer & Nüttgens 2000). Σε αυτή την εργασία προτιμήθηκε μια διαφορετική αρχιτεκτονική ονόματι ADONIS (BOC-Group 2016). Τα βασικά χαρακτηριστικά του γενικού μοντέλου αναφοράς διατηρήθηκαν. Δύο λόγοι οδήγησαν σε αυτή την μετάβαση. Ο πρώτος βασίζεται στα ευρήματα του Kovács (2016), ο οποίος κατέδειξε ότι η χρήση των μεθόδων μοντελοποίησης διαδικασιών στη βιβλιογραφία των κατασκευών είναι κατακερματισμένη. Ο δεύτερος λόγος είναι ότι πρόσφατες δημοσιεύσεις στη βιβλιογραφία των μοντέλων αναφοράς, π.χ. Verdouw et al. (2011), και τη βιβλιογραφία της διαχείρισης διαδικασιών στην κατασκευαστική βιομηχανία, όπως των Teixeira και Borsato (2015) και Cheng, Law, Bjornsson, Jones και R. D. Sriram (2010), έχουν χρησιμοποιήσει τη μέθοδο BPMN.

Βήμα 4: Δημιουργία του μερικού μοντέλου αναφοράς εφοδιαστικών αλυσίδων για την κατασκευαστική βιομηχανία.

Η δημιουργία του μερικού μοντέλου αναφοράς εφοδιαστικών αλυσίδων για την κατασκευαστική βιομηχανία βασίστηκε στα αποτελέσματα των προηγούμενων μεθοδολογικών βημάτων. Η οπτική των διαδικασιών απεικονίζεται γραφικά με τη χρήση αλυσίδας αξίας, λειτουργιών, διαδικασιών, και (όπου χρειάζεται) υποδιαδικασιών.

Βήμα 5: Επαλήθευση των διαδικασιών της εφοδιαστικής αλυσίδας στον κατασκευαστικό κλάδο

Μετά την ολοκλήρωση της προσέγγισης από την κορυφή προς τη βάση (top down), ακολούθησε η προσέγγιση από τη βάση προς την κορυφή (bottom up) με σκοπό την επαλήθευση των αποτελεσμάτων. Για αυτό το βήμα πραγματοποιήθηκαν ημι-δομημένες συνεντεύξεις με έμπειρα στελέχη της βιομηχανίας. Αρχικά, δημιουργήθηκαν τα ερωτηματολόγια με βάση τη μεθοδολογία που περιγράφεται από τον Saunders et al. (2016), τα οποία πραγματεύτηκαν τα παρακάτω θέματα: καθορισμός στρατηγικών εφοδιαστικής αλυσίδας και μέτρηση απόδοσης, διαχείριση σχέσεων με πελάτες και προμηθευτές, διαχείριση ζήτησης και ανάπτυξη νέων έργων, διαχείριση πακέτων εργασίας και ροής κατασκευής και τέλος, διαχείριση αξιώσεων. Οι συνεντεύξεις πραγματοποιήθηκαν με υψηλόβαθμα και έμπειρα στελέχη που εργάζονται σε μικρούς και μεγάλους αναδόχους. Εξαιτίας της υψηλής εξειδίκευσης, το ερωτηματολόγιο για τη διαχείριση αξιώσεων στόχευσε διαφορετικό προσωπικό σε σχέση με τα άλλα ερωτηματολόγια. Επιπλέον, μετά τη διεξαγωγή όλων των συνεντεύξεων, κρίθηκε απαραίτητο να πραγματοποιηθεί μία επιπλέον συνέντευξη με θέμα τη διαχείριση απόδοσης με έναν έμπειρο σύμβουλο επιχειρησιακών διαδικασιών. Ο παρακάτω **Πίνακας 1** απεικονίζει τον κατάλογο των συνεντεύξεων που πραγματοποιήθηκαν και το προφίλ των ερωτηθέντων. Οι εταιρείες και τα προσωπικά δεδομένα των ερωτηθέντων έχουν καταγραφεί αλλά δεν παρατίθενται για λόγους προστασίας προσωπικών δεδομένων.

Πίνακας 1: Κατάλογος συνεντεύξεων και προφίλ ερωτηθέντων

	Προφίλ Ερωτηθέντων					
Θέμα	Διευθυντής μικρομεσαίου αναδόχου με πλέον των 250 έργων (δημόσια και ιδιωτικά) που έχουν ολοκληρωθεί επιτυχώς στην Ελλάδα.	Διευθυντής μικρομεσαίου αναδόχου με πλέον των 100 έργων (ιδιωτικά) που έχουν ολοκληρωθεί με επιτυχία στην Ελλάδα.	Project manager σε μεγάλο ελληνικό ανάδοχο με εμπειρία σε διεθνή έργα.	Πρώην project manager σε μεγάλο ελληνικό ανάδοχο με εμπειρία σε διεθνή έργα / Σήμερα σύμβουλος αξιώσεων σε μεγάλη συμβουλευτική διαχείρισης αξιώσεων στο Η.Β.	Τεχνικός Διευθυντής έργων υποδομής σε μεγάλο ελληνικό ανάδοχο με διεθνή εμπειρία.	Σύμβουλος διαχείρισης επιχειρησιακών διαδικασιών στο πολωνικό παράρτημα της συμβουλευτικής BOC με διεθνή εμπειρία.
Καθορισμός στρατηγικών εφοδιαστικής αλυσίδας και μέτρηση απόδοσης	X	X			X	
Διαχείριση σχέσεων με πελάτες και προμηθευτές	X	X			X	
Διαχείριση ζήτησης και ανάπτυξη νέων έργων	X	X			X	
Διαχείριση πακέτων εργασίας και ροής κατασκευής	X	X		X	X	
Διαχείριση αξιώσεων			X	X		
Ανάπτυξη πλαισίου δεικτών KPI						X

Βήμα 6: Εντοπισμός βέλτιστων πρακτικών, οι οποίες δεν έχουν καταγραφεί στην υπάρχουσα βιβλιογραφία - Αναγνώριση διαφορών ανάμεσα σε εταιρείες διαφορετικού μεγέθους στη βιομηχανία.

Μετά την ολοκλήρωση της επαλήθευσης, το βήμα 6 εκμεταλλεύεται την εμπειρία και τη γνώση που συλλέχθηκε μέσω των συνεντεύξεων με δύο τρόπους. Πρώτον, οι μη καταγεγραμμένες βέλτιστες πρακτικές προστέθηκαν στο μοντέλο αναφοράς. Δεύτερον, πραγματοποιήθηκε μια σύγκριση των δεδομένων που συλλέχθηκαν από τους μικρούς και μεγάλους αναδόχους, σε μια προσπάθεια να τονιστούν οι διαφορές στις πρακτικές που ακολουθούν στις εφοδιαστικές αλυσίδες τους.

Η συγκεκριμένη μεθοδολογική προσέγγιση θεωρείται κατάλληλη για την επίτευξη του σκοπού αυτής της έρευνας. Τα κατασκευαστικά έργα μπορούν να αντιμετωπιστούν ως προσωρινοί οργανισμοί μέσα και ανάμεσα σε οργανισμούς και έτσι η τυποποίηση στο επίπεδο των πολλαπλών έργων είναι δύσκολη, καθώς οι ομάδες έργου και τα σχέδια των προϊόντων αλλάζουν από έργο σε έργο (Hofman et al. 2009). Η τυποποίηση μπορεί να επιτευχθεί μέσα από κοινές διαδικασίες, τις οποίες μοιράζονται οι παράγοντες ενός έργου. Επιπροσθέτως, η εστίαση του μοντέλου αναφοράς στον άξονα ενός χαρτοφυλακίου έργων και όχι σε μεμονωμένα έργα στρέφει την προσοχή στο γεγονός ότι ένας ανάδοχος μπορεί να αντιμετωπίσει τη ροή των έργων στο χαρτοφυλάκιο με τον ίδιο τρόπο που αντιμετωπίζεται η ροή προϊόντων σε μία γραμμή παραγωγής (Sacks 2016). Το μοντέλο αναφοράς που αναπτύχθηκε, περιέχει εννέα λειτουργίες, οι οποίες διαχωρίζονται σε διαχειριστικές, κύριες και υποστηρικτικές διαδικασίες, όπως τις περιγράφει ο Porter (1985). Τα διάφορα επίπεδα των διαδικασιών περιέχουν γενικές διαδικασίες που εστιάζουν στις δραστηριότητες/δράστες και ειδικές διαδικασίες που εστιάζουν στη ροή των πληροφοριών ανάμεσα στις δραστηριότητες και τους δράστες (Winch & Carr 2001). Η γενικευμένη προσέγγιση του μοντέλου αναφοράς στοχεύει στην παροχή μιας επισκόπησης ολόκληρης της διαδικασίας διαχείρισης εφοδιαστικών αλυσίδων μέσα από την περιγραφή των κύριων σταδίων και δραστηριοτήτων (Kagioglou & Aouad 1998). Ένα τέτοιο εργαλείο μπορεί να χρησιμοποιηθεί ως ένα συμπληρωματικό βήμα για τη βελτίωση της διαχείρισης διαδικασιών στις κατασκευαστικές εταιρείες. Το προτεινόμενο μοντέλο αναφοράς διαδικασιών εστιάζει στη μοντελοποίηση των δραστηριοτήτων ενός έργου και στις σχέσεις μεταξύ τους με τη χρήση διαγραμμάτων. Αυτό έχει ως αποτέλεσμα τη διαισθητική γραφική απεικόνιση που ασχολείται κατά κύριο λόγο με την καταγραφή και κατανόηση των διαδικασιών (Aguilar-Savén 2004; Recker et al. 2009).

Το μοντέλο εφοδιαστικής αλυσίδας REMEDY αναπτύχθηκε μέσα από το ερευνητικό έργο «ΟΔΥΣΣΕΑΣ: Ολιστική Διαχείριση της Μεταβλητότητας στις Σύγχρονες Εφοδιαστικές Αλυσίδες της Παγκοσμιοποιημένης Αγοράς». Εκτός από τα παραδοτέα του έργου τα οποία είναι διαθέσιμα διαδικτυακά (http://odysseus.simor.ntua.gr), η έρευνα έχει διαχυθεί μέσα από πλήθος δημοσιεύσεων στη διεθνή βιβλιογραφία (http://odysseus.simor.ntua.gr/project-results/publications.html). Το μοντέλο βασίζεται στη δομή του μοντέλου GSCF (Croxton et al.2001) περιλαμβάνοντας την αποδόμηση των διαδικασιών, το διαχωρισμό στρατηγικών και επιχειρησιακών λειτουργιών και την ανάλυση των λειτουργιών μέσα από μακροπρόθεσμες και βραχυπρόθεσμες διαδικασίες. Οι διαδικασίες του GSCF εμπλουτίστηκαν με γνώση που αποκτήθηκε μέσα από μελέτες περίπτωσης επιχειρησιακών διαδικασιών σε εφοδιαστικές αλυσίδες διάφορων κλάδων (ενέργεια, ξυλεία και επιπλοποιεία, σιδηρουργεία, καταναλωτικά αγαθά, τρόφιμα και ποτά, ρουχισμός, φαρμακευτικά και καλλυντικά). Αυτό επιτεύχθηκε μέσα από μία προσέγγιση από την κορυφή προς τη βάση (top down) και από τη βάση προς την κορυφή (bottom up), η οποία περιγράφεται αναλυτικά από τους Gayialis et al. (2013). Οι διαδικασίες του μοντέλου REMEDY συνδέθηκαν με ένα πλαίσιο δεικτών απόδοσης, το οποίο βασίστηκε στο μοντέλο SCOR (The Supply Chain Council 2010). Το μοντέλο επιχειρεί να εντοπίσει και να αξιολογήσει τις συνέπειες της κακής διαχείρισης της μεταβλητότητας της ζήτησης. Για να επιτύχει το στόχο του, χρησιμοποιεί πληθώρα οπτικών, συγκεκριμένα την οπτική λειτουργιών, την οπτική οργάνωσης, την οπτική πληροφοριών, την οπτική αποφάσεων, την οπτική κινδύνων, την οπτική γνώσης. Οι διαδικασίες διαδραματίζουν κεντρικό ρόλο στο μοντέλο, καθώς συνδέουν όλες τις υπόλοιπες οπτικές. Το λογισμικό ARIS platform χρησιμοποιήθηκε για να υποστηρίξει την ολοκλήρωση των παραπάνω οπτικών. Οι διαδικασίες εκτείνονται σε τρία επίπεδα μιας εφοδιαστικής αλυσίδας (προμηθευτής, εταιρεία, πελάτης). Το μοντέλο περιέχει εννέα κύριες λειτουργίες: καθορισμός στρατηγικών εφοδιαστικής αλυσίδας, διαχείριση σχέσεων με πελάτες, ανάπτυξη και εμπορευματοποίηση προϊόντων, διαχείριση σχέσεων με προμηθευτές, δημιουργία πλαισίου μέτρησης απόδοσης, διαχείριση ζήτησης, ικανοποίηση παραγγελιών, διαχείριση ροής παραγωγής, διαχείριση επιστροφών. Όλες οι λειτουργίες αναλύονται μέσα από δέντρα λειτουργιών σε στρατηγικές και επιχειρησιακές διαδικασίες. Το στρατηγικό επίπεδο σχετίζεται με τον καθορισμό μακροπρόθεσμων δραστηριοτήτων και το επιχειρησιακό επίπεδο σχετίζεται με τη βραχυπρόθεσμη εκτέλεση των δραστηριοτήτων. Κάθε διαδικασία αναλύεται μέσα από διαγράμματα eEPC, τα οποία ολοκληρώνουν τις οπτικές λειτουργιών, οργάνωσης, πληροφοριών, γνώσης και κινδύνων. Το μοντέλο αποτελείται από ένα διάγραμμα αλυσίδας αξίας, εννέα δέντρα λειτουργιών, ενενήντα δύο eEPC, δεκατέσσερα δέντρα κινδύνων, εννέα δέντρα αποφάσεων, τρία οργανογράμματα, και ένα διάγραμμα πληροφοριακών συστημάτων. Η οπτική γνώσης συσχετίστηκε με τις σημαντικότερες αποφάσεις που απεικονίζονται στο μοντέλο. Επιπλέον, το μοντέλο συνοδεύεται από λογισμικό ανάλυσης κινδύνων και μαθηματικά μοντέλα υποστήριξης αποφάσεων. Οι κίνδυνοι που περιλαμβάνονται αφορούν επιχειρησιακούς, περιβαλλοντικούς και οικονομικούς κινδύνους σε μία εφοδιαστική αλυσίδα. Τα ποσοτικά μοντέλα και οι αλγόριθμοι που χρησιμοποιούνται στην υποστήριξη αποφάσεων έχουν ως στόχο την ακριβή πρόβλεψη της ζήτησης και την αποδοτική αναπλήρωση αποθεμάτων. Το μοντέλο REMEDY στοχεύει στη διαχείριση της μεταβλητότητας της ζήτησης σε πλήθος βιομηχανιών μέσα από τη γενική του φύση. Έχουν αναπτυχθεί μερικά μοντέλα αναφοράς που εστιάζουν στους κλάδους παραγωγής για απόθεμα (make-to-stock), παραγωγής κατά παραγγελία (make-to-order), υβριδικής παραγωγής (hybrid) και ενέργειας (energy).

4. Μοντέλο αναφοράς εφοδιαστικής αλυσίδας κατασκευών

Το μοντέλο αναφοράς διαδικασιών REMEDY επιλέχθηκε ως βάση για την ανάπτυξη του μοντέλου αναφοράς για τις εφοδιαστικές αλυσίδες του κατασκευαστικού κλάδου. Το μοντέλο REMEDY μπορεί να εφαρμοστεί σε οποιοδήποτε στάδιο της παραγωγικής εφοδιαστικής αλυσίδας με μικρές τροποποιήσεις. Οι ιδιαιτερότητες της εφοδιαστικής αλυσίδας των κατασκευών, ωστόσο, επιβάλλουν στο μοντέλο να εστιάσει σε συγκεκριμένο στάδιο στην εφοδιαστική αλυσίδα. Ο ανάδοχος επιλέχθηκε ως το σημείο εστίασης του μοντέλου, αφού οι ανάδοχοι κατέχουν την τεχνική και διαχειριστική ικανότητα να ολοκληρώσουν το έργο για τον πελάτη. Η επιλογή αυτή συμπίπτει με την περιγραφή που παρέχει ο Ronchi (2006) για τους αναδόχους, σύμφωνα με την οποία: ο κύριος παράγοντας είναι ο ανάδοχος, ο οποίος επιλέγει, οργανώνει, συντονίζει και διαχειρίζεται υπεργολάβους και ειδικούς κατά μήκος της εφοδιαστικής αλυσίδας των κατασκευών. Επιπλέον, οι ανάδοχοι συνδέονται στενά με την επιτυχία ενός έργου (Alzahrani & Emsley 2013) και οι πελάτες δεν συνηθίζουν να συμμετέχουν στις πρακτικές που διέπουν τις συμβάσεις των έργων (London et al. 1998; Cox et al. 2006b). Κατάντης του αναδόχου είναι ο πελάτης, ο σύμβουλος και ο σχεδιαστής, οι οποίοι θεωρούνται ως «Πελάτης» στο μοντέλο, καθώς οι συγκεκριμένοι οργανισμοί εμπλέκονται στο έργο μετά από επιθυμία του πελάτη και αντιπροσωπεύουν τα ενδιαφέροντα αυτού. Άναντες του αναδόχου είναι οι υπεργολάβοι (οι οποίοι μπορούν να προσφέρουν υλικά, υπηρεσίες ή τεχνογνωσία) που θεωρούνται «Προμηθευτές», καθώς τέτοιοι οργανισμοί εμπλέκονται στο έργο με σκοπό να παρέχουν στους αναδόχους αυτά που τους ζητήθηκαν. Η πλειονότητα των σχέσεων του αναδόχου με τους υπεργολάβους βασίζεται σε οικονομικά, τεχνικά, συμβατικά και διαπροσωπικά χαρακτηριστικά, τα οποία επεκτείνονται σε ένα στάδιο της εφοδιαστικής αλυσίδας (Pala et al. 2013). Σύμφωνα με την προσέγγιση που ακολουθήθηκε κατά την ανάπτυξη του μοντέλου REMEDY, το μοντέλο που περιγράφεται σε αυτό το κεφάλαιο θεωρείται μερικό μοντέλο αναφοράς, καθώς εστιάζει σε μια συγκεκριμένη βιομηχανία. Η αρχική δομή του μοντέλου REMEDY ήταν εστιασμένη στην παραγωγή και έτσι χρειάστηκε ένα πλήθος αλλαγών για τη δημιουργία του μοντέλου που περιγράφει την κατασκευαστική βιομηχανία. Οι παρακάτω πίνακες (**Πίνακας 2** και **Πίνακας 3)** απεικονίζουν κάποιες από τις διαφορές ανάμεσα στα δύο μοντέλα.

Σε περεταίρω ανάλυση, για τις ανάγκες του μερικού μοντέλου αναφοράς πραγματοποιήθηκαν αλλαγές στην ονομασία λειτουργιών ώστε αυτές να περιγράφουν τον κλάδο των κατασκευών. Το πλήθος των διαδικασιών μεταβλήθηκε καθώς δημιουργήθηκαν νέες διαδικασίες, αφαιρέθηκαν διαδικασίες ή ενοποιήθηκαν διαδικασίες με στόχο το μερικό μοντέλο αναφοράς να περιγράφει ξεκάθαρα τον κλάδο των κατασκευών. Η αλυσίδα αξίας του μοντέλου αναφοράς αποτελείται από τέσσερις διαχειριστικές, τέσσερις κύριες και μια υποστηρικτική λειτουργία. Το μοντέλο εστιάζει στην ολοκλήρωση των διαδικασιών και των ροών μεταξύ των συμμετεχόντων, όπως ακριβώς προτείνει η ευρύτερη βιβλιογραφία της διαχείρισης εφοδιαστικών αλυσίδων (Bankvall et al. 2010). Το μοντέλο επιχειρεί να καλύψει και να ενοποιήσει έννοιες οι οποίες έχουν διαχρονικά αναδειχθεί από τη βιβλιογραφία όπως είναι οι σχέσεις εντός της εφοδιαστικής αλυσίδας από διάφορες οπτικές (Harland 1996), στενά συνδεδεμένες λειτουργικές περιοχές εντός της εφοδιαστικής αλυσίδας των κατασκευών (Benton & McHenry 2010), και τα στάδια του σχεδιασμού, της κατασκευής και της παράδοσης του κατασκευαστικού έργου (Olander & Landin 2005) με στόχο τον επαρκή έλεγχο επί των αποτελεσμάτων του έργου (Bildsten & Manley 2015).

Πίνακας 2: Διαφορές ανάμεσα στο γενικό και το μερικό μοντέλο αναφοράς

Γενικό μοντέλο REMEDY		Μερικό μοντέλο κατασκευών REMEDY	
Λειτουργίες	Πλήθος διαδικασιών	Λειτουργίες	Πλήθος διαδικασιών
Καθορισμός στρατηγικών διαχείρισης εφοδιαστικών αλυσίδων	8	Καθορισμός στρατηγικών διαχείρισης εφοδιαστικών αλυσίδων	3
Διαχείριση σχέσεων με πελάτες	16	Διαχείριση σχέσεων με πελάτες	14
Ανάπτυξη νέων προϊόντων και εμπορευματοποίηση	12	Ανάπτυξη νέων έργων και εμπορευματοποίηση	9
Διαχείριση σχέσεων με προμηθευτές	10	Διαχείριση σχέσεων με προμηθευτές	11
Ανάπτυξη πλαισίου δεικτών απόδοσης	8	Ανάπτυξη πλαισίου δεικτών απόδοσης	2
Διαχείριση ζήτησης	9	Διαχείριση ζήτησης	9
Ικανοποίηση παραγγελιών	10	Διαχείριση πακέτων εργασίας	8
Διαχείριση ροής παραγωγής	7	Διαχείριση ροής κατασκευής	7
Διαχείριση επιστροφών	10	Διαχείριση αξιώσεων	5

Πίνακας 3: Εύρος τροποποιήσεων στις διαδικασίες του γενικού μοντέλου αναφοράς

Λειτουργία	# διαδικασιών γενικού μοντέλου που διατηρήθη-καν	# διαδικασιών που διαγράφη-καν	# νέων διαδικασιών	# διαδικασιών που προσαρμό-στηκαν	Σύνολο διαδικασιών
Καθορισμός στρατηγικών διαχείρισης εφοδιαστικών αλυσίδων	0	8	3	0	3
Διαχείριση σχέσεων με πελάτες	3	2	2	9	14
Ανάπτυξη νέων έργων και εμπορευματο ποίηση	2	0	0	7	9
Διαχείριση σχέσεων με προμηθευτές	1	1	3	8	11
Ανάπτυξη πλαισίου δεικτών απόδοσης	0	8	2	0	2
Διαχείριση ζήτησης	1	0	0	7	9

Λειτουργία	**# διαδικασιών γενικού μοντέλου που διατηρήθη-καν**	**# διαδικασιών που διαγράφη-καν**	**# νέων διαδικασιών**	**# διαδικασιών που προσαρμό-στηκαν**	**Σύνολο διαδικασιών**
Διαχείριση πακέτων εργασίας	0	10	8	0	8
Διαχείριση ροής κατασκευής	0	3	3	4	7
Διαχείριση αξιώσεων	0	10	5	0	5

4.1. Καθορισμός στρατηγικών διαχείρισης εφοδιαστικών αλυσίδων

Η λειτουργία «Καθορισμός στρατηγικών διαχείρισης εφοδιαστικών αλυσίδων» είναι η πρώτη διαχειριστική λειτουργία στο μοντέλο αναφοράς και στοχεύει στην οριοθέτηση των στρατηγικών που θα ακολουθηθούν στις άλλες οκτώ λειτουργίες του μοντέλου. Οι στρατηγικές πρέπει να διαμορφώνονται για κάθε λειτουργία χωριστά και για όλες τις λειτουργίες ταυτόχρονα έτσι ώστε να αποφεύγονται αντιθέσεις ανάμεσα στις διάφορες επιμέρους στρατηγικές. Η εστίαση της συνολικής στρατηγικής πρέπει να σχετίζεται με την ολοκλήρωση των διαδικασιών, των ροών, των συστημάτων και των παραγόντων (Bankvall et al. 2010). Οι μικρο-διαχειριστικές αποφάσεις δεν αποτελούν αντικείμενο της συγκεκριμένης λειτουργίας καθώς είναι δύσκολες στην πρόβλεψή τους και αφήνονται στο λειτουργικό επίπεδο (Isatto & Formoso 2011). Η λειτουργία περιλαμβάνει τρεις διαδικασίες, τις «Καθορισμός στρατηγικών για τις διαχειριστικές διαδικασίες», «Καθορισμός στρατηγικών για τις υποστηρικτικές διαδικασίες» και «Καθορισμός στρατηγικών για τις κύριες διαδικασίες». Ειδικά όταν οι στρατηγικές στοχεύουν στην ολοκλήρωση της εφοδιαστικής αλυσίδας, είναι σημαντική η εξέταση των στρατηγικών που σχετίζονται με την πολυπλοκότητα των προμηθειών, την αβεβαιότητα της ζήτησης, την ποικιλία των προϊόντων και το σημείο αποσύνδεσης της εφοδιαστική αλυσίδας (Eriksson 2015). Η μερική βελτιστοποίηση είναι συχνό φαινόμενο και, για το λόγο αυτό, είναι απαραίτητη μια ολιστική προσέγγιση στη διαχείριση της εφοδιαστικής αλυσίδας η οποία περιλαμβάνει, μεταξύ άλλων, την επιλογή των προμηθευτών, την επιλογή της τοποθεσίας των εγκαταστάσεων και την επιλογή των καναλιών διανομής (Christopher et al. 2006).

4.2. Διαχείριση σχέσεων με πελάτες

Η λειτουργία «Διαχείριση σχέσεων με πελάτες» είναι η δεύτερη διαχειριστική λειτουργία του μοντέλου αναφοράς και περιλαμβάνει όλες τις διαδικασίες που σχετίζονται με την επιλογή, τη διαχείριση, την ομαδοποίηση, τη διαπραγμάτευση και την ικανοποίηση των πελατών. Οι Nguyen et al. (2008) ερεύνησαν τη σύγχρονη βιβλιογραφία και εντόπισαν ότι η εξυπηρέτηση πελατών είναι μια διαχειριστική λειτουργία με μεγάλη βαρύτητα στην βιομηχανία των οικιστικών κατασκευών. Η λειτουργία που περιγράφεται στο μοντέλο επεκτείνει την ικανοποίηση πελατών σε διαχείριση σχέσεων με τους πελάτες με την προσθήκη περισσότερων διαδικασιών που σχετίζονται με τους πελάτες. Ο (2001; σ.96 όπως των παραθέτουν οι Sear et al. (2008)) εντοπίζει πέντε κρίσιμους παράγοντες στη βιβλιογραφία.

Αυτοί είναι: 1. η εφαρμογή μιας πελατοκεντρικής στρατηγικής, 2. η δημιουργία οργανωτικής δομής φιλικής προς τα συστήματα διαχείρισης σχέσεων με τους πελάτες, 3. η εγκαθίδρυση φιλοσοφίας φιλικής προς τα συστήματα διαχείρισης σχέσεων με τους πελάτες, 4. η δέσμευση των υψηλόβαθμων στελεχών, και 5. ο καθορισμός μέτρων επιτυχίας της διαχείρισης των σχέσεων με τους πελάτες. Η εστίαση της στρατηγικής διαχείρισης σχέσεων με τους πελάτες θα πρέπει να σχετίζεται με τη διατήρηση των υπαρχόντων πελατών μέσω της συνεχούς επαφής, την ανάπτυξη αξίας για τον πελάτη σε βάθος χρόνου με βάρος στην εξυπηρέτηση του πελάτη, και τη δέσμευση στην ικανοποίηση των απαιτήσεων του πελάτη (Smyth et al. 2009). Η λειτουργία που περιγράφεται αποτελείται από δεκατέσσερις διαδικασίες, πέντε στρατηγικές και εννέα λειτουργικές. Ο διαχωρισμός αυτός βασίζεται στη διαπίστωση των Preece et al. (2015) σύμφωνα με την οποία η φιλοσοφία, τα εργαλεία και οι τεχνικές της διαχείρισης των σχέσεων με τους πελάτες έχουν και στρατηγικές και λειτουργικές παραμέτρους. Οι στρατηγικές διαδικασίες είναι οι ακόλουθες: «Καθορισμός κριτηρίων κατηγοριοποίησης πελατών», «Ανάπτυξη κατευθύνσεων για το επίπεδο διαφοροποίησης στις συμβάσεις έργων/παροχής υπηρεσιών», «Ανάπτυξη κατευθύνσεων για τη μεταφορά των πλεονεκτημάτων που προκύπτουν από τη βελτίωση των διαδικασιών προς τους πελάτες», «Ανάπτυξη διαδικασιών για την ανταπόκριση στους πελάτες», και «Ανάπτυξη πληροφοριακής υποδομής για τις διαδικασίες διαχείρισης σχέσεων με τους πελάτες». Οι στρατηγικές διαδικασίες μπορούν να εκτελεστούν ανεξάρτητα η μία από τις άλλες και όταν αυτό κρίνεται απαραίτητο. Οι λειτουργικές διαδικασίες είναι οι παρακάτω: «Κατηγοριοποίηση πελατών», «Προετοιμασία ομάδων διαχείρισης λογαριασμών πελατών», «Επανεξέταση λογαριασμών πελατών και αναγνώριση ευκαιριών», «Διαπραγμάτευση σύμβασης έργου/ παροχής υπηρεσιών με τον πελάτη», «Εφαρμογή σύμβασης έργου/ παροχής υπηρεσιών με τον πελάτη», «Αναγνώριση γεγονότος», «Αξιολόγηση περίπτωσης και επίλυση γεγονότος», «Αξιολόγηση επιπέδου ικανοποίησης πελάτη», και «Μέτρηση απόδοσης της διαχείρισης σχέσεων με τους πελάτες». Οι πρώτες τέσσερις διαδικασίες εκτελούνται πριν την υπογραφή της σύμβασης νέου έργου και επόμενες τέσσερις μετά την υπογραφή της σύμβασης. Η τελευταία διαδικασία μπορεί να εκτελεστεί κατόπιν ή/και παράλληλα των οκτώ προηγούμενων. Για να στεφθεί με επιτυχία η υιοθέτηση ενός συστήματος διαχείρισης σχέσεων με τους πελάτες είναι απαραίτητο να μελετηθούν εξονυχιστικά οι αξίες, οι αντιλήψεις, τα συναισθήματα και τα κίνητρα που διέπουν το προσωπικό (Sear et al. 2008). Η σημασία ενός τέτοιου μοντέλου διαφαίνεται στη δήλωση του Rowlinson (2005) σύμφωνα με την οποία η διαχείριση σχέσεων είναι κάτι περισσότερο από χαρακτηριστικό της διοίκησης έργων, είναι παράγοντας κλειδί από τον οποίο εξαρτάται η επιτυχία του έργου.

4.3. Ανάπτυξη νέων έργων και εμπορευματοποίηση

Η λειτουργία «Ανάπτυξη νέων έργων και εμπορευματοποίηση» είναι η τρίτη διαχειριστική λειτουργία του μοντέλου αναφοράς και περιλαμβάνει διαδικασίες που σχετίζονται με την ανάλυση, επιλογή και ανάπτυξη νέων έργων. Αποτελείται από εννέα διαδικασίες, τέσσερις στρατηγικές και πέντε λειτουργικές. Τα έργα μπορούν να αντιμετωπιστούν ως νέο προϊόν αν παρατηρηθούν από τη σκοπιά της παραγωγικής διαδικασίας, ωστόσο, όπως τονίζουν οι Rogers et al. (2004), είναι σημαντικό να υπάρχουν τα σωστά άτομα από τις εσωτερικές λειτουργίες παράλληλα με πελάτες και προμηθευτές κλειδιά στη διαδικασία ανάπτυξης προϊόντων και εμπορευματοποίησης. Οι στρατηγικές διαδικασίες είναι οι παρακάτω και μπορούν να εκτελούνται όποτε χρειαστεί χωρίς να ακολουθείται κάποια συγκεκριμένη σειρά: «ανάπτυξη διαδικασίας γένεσης και αξιολόγησης ιδεών», «ανάπτυξη κατευθύνσεων για την επιλογή του προσωπικού ανάπτυξης του έργου», «εντοπισμός προβλημάτων και περιορισμών για την έναρξη νέων έργων» και «ανάπτυξη κατευθύνσεων για την ανάπτυξη νέων έργων». Αυτές οι διαδικασίες παρέχουν κατευθυντήριες γραμμές για την εκτέλεση των λειτουργικών διαδικασιών. Οι λειτουργικές διαδικασίες είναι οι παρακάτω: «καθορισμός νέων έργων και αξιολόγηση καταλληλότητας», «σχηματισμός ομάδας ανάπτυξης έργου», «επισημοποίηση ανάπτυξης νέου έργου», «αξιολόγηση απόφασης για ίδια κατασκευή/υπεργολαβία» και «μέτρηση απόδοσης της ανάπτυξης νέων έργων και εμπορευματοποίησης». Οι πρώτες τέσσερις λειτουργικές διαδικασίες εκτελούνται σειριακά, αλλά η πέμπτη μπορεί να εκτελεστεί είτε εν σειρά είτε παράλληλα με τις προηγούμενες λειτουργικές διαδικασίες. Η εμπορευματοποίηση στην κατασκευαστική βιομηχανία εξαρτάται από τον τύπο της σύμβασης που υπογράφεται με τον πελάτη. Οι επιλογές εκτείνονται από το απλό «σχεδιασμός-μειοδοσία-κατασκευή» μέχρι εξαιρετικά πολύπλοκες συμφωνίες. Η σύναψη συμβάσεων και συμφωνιών εξετάζεται στις λειτουργίες «διαχείριση σχέσεων με τους πελάτες» και «διαχείριση σχέσεων με τους προμηθευτές», ως εκ τούτου η εμπορευματοποίηση δεν αναλύεται στις διαδικασίες αυτής της ενότητας.

4.4. Διαχείριση σχέσεων με προμηθευτές

Η λειτουργία «διαχείριση σχέσεων με προμηθευτές» είναι η τέταρτη διαχειριστική λειτουργία του μοντέλου και περιλαμβάνει όλες τις διαδικασίες που σχετίζονται με την επιλογή, τη διαχείριση, την κατηγοριοποίηση, την υποβολή προσφορών, την προμήθεια και τη διαπραγμάτευση με τους προμηθευτές. Μία εξορθολογισμένη λειτουργία διαχείρισης σχέσεων με τους προμηθευτές μπορεί να παρέχει στον ανάδοχο μία σταθερή και αποδοτική ροή υλικών, πληροφοριών και κεφαλαίου (Gou et al. 2011). Οι ανάδοχοι πρέπει να βελτιστοποιήσουν τη βάση προμηθευτών σε σχέση με το πλήθος και την ποιότητα των προμηθευτών, να αυξήσουν την προσοχή τους στο υφιστάμενο χαρτοφυλάκιο των προμηθευτών, να επιλέξουν το επίπεδο ολοκλήρωσης των προμηθευτών στις διαδικασίες τους και να παρακολουθούν την απόδοση των προμηθευτών τους (Bemelmans, Voordijk, Vos, et al. 2012). Οι διαδικασίες της λειτουργίας πρέπει να είναι επαρκώς ευέλικτες, ώστε να προσαρμόζονται στις απαιτήσεις διαχείρισης των πρώτων υλών όλων των έργων σε ένα χαρτοφυλάκιο (Safa et al. 2014). Η λειτουργία αποτελείται από έντεκα διαδικασίες, τρεις στρατηγικές και οχτώ λειτουργικές. Προηγούμενες εργασίες που έχουν υιοθετήσει τη συγκεκριμένη προσέγγιση περιλαμβάνουν αυτές από τους Lambert και Schwieterman (2012), Pala et al. (2013) και van Lith et al. (2015). Οι στρατηγικές διαδικασίες έχουν ως στόχο να παρέχουν τις κατευθυντήριες γραμμές για την αποτελεσματική διαχείριση των προμηθευτών και είναι οι παρακάτω: «καθορισμός κριτηρίων για την κατηγοριοποίηση των προμηθευτών», «ανάπτυξη κατευθύνσεων για το επίπεδο ευελιξίας στις συμβάσεις έργου/παροχής υπηρεσιών» και «ανάπτυξη κατευθύνσεων για την μεταφορά των πλεονεκτημάτων που προκύπτουν από τη βελτίωση των διαδικασιών στους προμηθευτές». Οι στρατηγικές διαδικασίες μπορούν να εκτελεστούν όποτε κριθεί απαραίτητο και χωρίς κάποια συγκεκριμένη σειρά. Οι λειτουργικές διαδικασίες σχετίζονται με την καθημερινή αλληλεπίδραση με τους προμηθευτές και είναι οι παρακάτω: «κατηγοριοποίηση προμηθευτών», «προετοιμασία ομάδων διαχείρισης λογαριασμών προμηθευτών», «εξέταση λογαριασμών προμηθευτών και εντοπισμός ευκαιριών», «διενέργεια μειοδοσίας προμηθευτών», «επιλογή προμηθευτών και προμήθεια», «διαπραγμάτευση συμβάσεων έργου/παροχής υπηρεσιών με προμηθευτές», «εκτέλεση συμβάσεων έργου/παροχής υπηρεσιών με προμηθευτές» και «μέτρηση απόδοσης της διαχείρισης σχέσεων με τους προμηθευτές». Οι πρώτες τρεις διαδικασίες εκτελούνται πριν υπογραφεί η σύμβαση για ένα νέο έργο και οι τέσσερις επόμενες εκτελούνται αφού υπογραφεί η σύμβαση έργου με τον πελάτη. Η τελευταία διαδικασία μπορεί να εκτελεστεί είτε αφού εκτελεστούν οι επτά προηγούμενες διαδικασίες είτε ταυτόχρονα με αυτές. Η σημασία ενός μοντέλου για τη διαχείριση των σχέσεων με τους προμηθευτές, όπως και η αντίστοιχη για τους πελάτες, διαφαίνεται στη δήλωση του Rowlinson (2005) σύμφωνα με την οποία η διαχείριση σχέσεων είναι κάτι περισσότερο από χαρακτηριστικό της διοίκησης έργων, είναι παράγοντας κλειδί από τον οποίο εξαρτάται η επιτυχία του έργου.

4.5. Ανάπτυξη πλαισίου δεικτών απόδοσης

Οι συνεντεύξεις που έλαβαν χώρα, έδειξαν ότι μόνο οι μεγάλοι ανάδοχοι έχουν εφαρμόσει σε κάποιο βαθμό πρακτικές διαχείρισης διαδικασιών μέσα από την υιοθέτηση των προτύπων ISO και μετρούν την απόδοση των διαδικασιών τους μέσα από τους δείκτες που παρέχουν αυτά τα πρότυπα. Αυτό σημαίνει ότι υπάρχει ανάγκη για ένα πλαίσιο διαχείρισης διαδικασιών, το οποίο μπορεί να υιοθετηθεί από οποιαδήποτε κατασκευαστική εταιρεία. Το μοντέλο που περιγράφεται σε αυτήν την ενότητα αποτελείται από δύο διαδικασίες. Οι διαδικασίες αυτές, σύμφωνα με την κατηγοριοποίηση του Porter (1985), θεωρούνται υποστηρικτικές διαδικασίες. Δεν είναι απαραίτητη η σειριακή τους εκτέλεση, αλλά η ταυτόχρονη εκτέλεσή τους μπορεί να δώσει καλύτερα αποτελέσματα. Η πρώτη διαδικασία είναι η «αξιολόγηση ωριμότητας διαδικασιών». Η κύρια υπόθεση της μοντελοποίησης ωριμότητας διαδικασιών είναι ότι η ποιότητα ενός προϊόντος είναι στενά συνδεδεμένη με την ποιότητα των διαδικασιών που ακολουθούνται για την ανάπτυξή του (Paulk et al. 1993). Οι Hutchinson και Finnemore (1999) εντόπισαν αποδείξεις προερχόμενες από άλλους τομείς, οι οποίες συνδέουν την συνεχή βελτίωση των διαδικασιών με πολλά μικρά εξελικτικά βήματα και όχι με επαναστατικά μέτρα. Οι Willis και Rankin (2012) αναφέρονται σε αυτό το εξελικτικό μονοπάτι ως πλαίσιο ωριμότητας διαδικασιών και συμφωνούν με τη γενικότερη συναίνεση ότι η βελτίωση των διαδικασιών αποτελείται από πολλά προοδευτικά στάδια, τα οποία, αν ακολουθηθούν σωστά, αυξάνουν την αποτελεσματικότητα μιας διαδικασίας σε σχέση επίτευξη των στόχων της. Η δεύτερη διαδικασία είναι η «ανάπτυξη πλαισίου δεικτών μέτρησης απόδοσης». Είναι σημαντικό η πρώτη διαδικασία να έχει εκτελεστεί τουλάχιστον μία φορά πριν την υιοθέτηση της δεύτερης. Όπως υποστηρίζουν οι Oliveira et al. 2012, η επίδραση της ανάλυσης των δεικτών απόδοσης εξαρτάται από την ωριμότητα των διαδικασιών διαχείρισης εφοδιαστικής αλυσίδας μιας εταιρείας. Το πλαίσιο δεικτών μέτρησης απόδοσης πρέπει να χαρακτηρίζεται από μία ολιστική οπτική συστημάτων, η οποία θα ξεπερνά τα πλαίσια της εταιρείας (Chan & Qi 2003). Οι Cai et al. (2009) προτείνουν την υιοθέτηση πολλών διαχειριστικών διαδικασιών σε ένα σύστημα διαχείρισης απόδοσης, όπως για παράδειγμα διαδικασίες που: αναγνωρίζουν δείκτες, ορίζουν στόχους, σχεδιάζουν, επικοινωνούν, παρακολουθούν, αναφέρουν και παρέχουν ανάδραση. Οι Li et al. (2006) πιστεύουν ότι υψηλότερα επίπεδα υιοθέτησης πρακτικών διαχείρισης εφοδιαστικής αλυσίδας, όπως υψηλότερα επίπεδα διαχείρισης ποιότητας και διαμοιρασμού πληροφοριών, μπορούν να οδηγήσουν σε ενίσχυση του ανταγωνιστικού πλεονεκτήματος και σε βελτιωμένη απόδοση. Οι δείκτες απόδοσης καθοδηγούν τους αναδόχους στην προσπάθεια βελτίωσης των διαδικασιών τους και κατά συνέπεια βελτιώνουν την συνολική απόδοση του έργου (Thunberg & Pearsson 2014). Η βελτιωμένη απόδοση σε ένα έργο μπορεί να οδηγήσει σε πιο επιτυχημένα έργα, αφού η επιτυχία σε ένα έργο συνδέεται συχνά και μετράται με το βαθμό συμμόρφωσης σε ένα προκαθορισμένο επίπεδο απόδοσης (Parfitt & Sanvido 1993). Πρέπει να σημειωθεί ότι δεν υπάρχει ένας μοναδικός τρόπος εκτέλεσης των διαδικασιών αυτών, ένα σχόλιο το οποίο διατυπώθηκε κατά την εξειδικευμένη συνέντευξη. Αυτό σημαίνει ότι οι διαδικασίες που περιγράφονται σε αυτό το μοντέλο είναι ανοιχτές σε μεγάλο βαθμό τροποποιήσεων ανάλογα με την εμπειρία κάθε επαγγελματία. Ωστόσο, αφού οι συνεντεύξεις με επαγγελματίες του κατασκευαστικού κλάδου ανέδειξαν την έλλειψη τέτοιων πρακτικών, η παρουσίασή τους έχει μεγάλη σημασία.

4.6. Διαχείριση ζήτησης

Για να μπορεί μια εταιρεία να λειτουργήσει προληπτικά στην αναμενόμενη ζήτηση και να αντιμετωπίσει την μη αναμενόμενη ζήτηση, είναι απαραίτητη μια επαρκής διαδικασία διαχείρισης της ζήτησης (Croxton et al. 2002). Μια τέτοια διαδικασία, σύμφωνα με τους Wong et al. (2007), επιτρέπει στις εταιρείες να επωφεληθούν από την πρόγνωση της ζήτησης και να αποφύγουν καταστροφές μέσα από την πρόβλεψη της εμφάνισής τους. Η λειτουργία «διαχείρισης ζήτησης» αποτελείται από εννέα διαδικασίες, τέσσερις στρατηγικές και πέντε λειτουργικές. Οι στρατηγικές διαδικασίες συνήθως εκτελούνται μία ή δύο φορές το χρόνο και η εκτέλεσή τους μπορεί να είναι σειριακή ή παράλληλη. Οι στρατηγικές διαδικασίες είναι οι: «καθορισμός διαδικασιών πρόγνωσης ζήτησης», «σχεδιασμός ροών πληροφοριών», «καθορισμός διαδικασιών συγχρονισμού» και «ανάπτυξη διαδικασιών διαχείρισης έκτακτων αναγκών». Οι λειτουργικές διαδικασίες εκτελούνται όσο συχνά απαιτείται και ακολουθούν σειριακή ροή με εξαίρεση τη διαδικασία που σχετίζεται με τη μέτρηση απόδοσης, η οποία μπορεί να εκτελεστεί είτε εν σειρά είτε παράλληλα με τις υπόλοιπες λειτουργικές διαδικασίες. Οι λειτουργικές διαδικασίες είναι: «συλλογή δεδομένων εισόδου για την πρόγνωση», «πρόγνωση», «συγχρονισμός πρόγνωσης ζήτησης με την κατασκευή, τις προμήθειες και την υλικοτεχνική υποστήριξη», «μείωση μεταβλητότητας της ζήτησης και/ή αύξηση ευελιξίας» και «μέτρηση απόδοσης διαχείρισης ζήτησης». Η έλλειψη μοντέλων διαδικασιών διαχείρισης της ζήτησης στη βιβλιογραφία, ειδικά στη βιβλιογραφία των κατασκευών, σημαίνει ότι οι διαδικασίες που περιγράφονται σε αυτήν την ενότητα έχουν βαριά επιρροή από την εργασία των Croxton et al. (2002).

4.7. Διαχείριση πακέτων εργασίας

Όπως και στην εργασία των Kim και Ibbs (1995), το μοντέλο που παρουσιάζεται σε αυτήν την ενότητα δημιουργήθηκε με την αναγνώριση των κύριων παραμέτρων που επηρεάζουν αποφάσεις της διαδικασίας διαχείρισης πακέτων εργασίας και εμπλουτίζοντας τα βασικά χαρακτηριστικά τους με σημαντικές εργασίες. Η λειτουργία διαχείρισης πακέτων εργασίας αποτελείται από οκτώ διαδικασίες, τέσσερις στρατηγικές και τέσσερις λειτουργικές. Οι διαδικασίες διαχείρισης πακέτων εργασίας έχουν χωριστεί με παρόμοιο τρόπο και στο παρελθόν στην εργασία των Kim και Ibbs (1995). Οι τέσσερις στρατηγικές διαδικασίες μπορούν να εκτελεστούν είτε παράλληλα είτε σειριακά ανάλογα με τις ανάγκες της εταιρείας. Οι στρατηγικές διαδικασίες είναι: «καθορισμός απαιτήσεων διαχείρισης πακέτων εργασίας», «αξιολόγηση δικτύου εφοδιαστικής αλυσίδας», «σχεδιασμός ολοκλήρωσης πακέτων εργασίας» και «ανάπτυξη διαδικασιών διαχείρισης εκτάκτων αναγκών εντός του έργου». Οι στρατηγικές διαδικασίες μπορεί να αφορούν ένα συγκεκριμένο έργο ή ολόκληρο το χαρτοφυλάκιο έργων. Οι λειτουργικές διαδικασίες εκτελούνται σειριακά με την εξαίρεση της διαδικασίας που σχετίζεται με την μέτρηση της απόδοσης, η οποία μπορεί να εκτελεστεί είτε εν σειρά είτε παράλληλα με τις άλλες. Οι λειτουργικές διαδικασίες εστιάζουν στα πακέτα εργασίας ενός συγκεκριμένου έργου κα είναι οι παρακάτω: «προετοιμασία και επικοινωνία πακέτων εργασίας», «επεξεργασία πακέτου εργασίας», «διαχείριση εγγράφων» και «εκτέλεση ποιοτικού ελέγχου και μέτρηση απόδοσης». Οι Li et al. (2006) στην εργασία τους ανέπτυξαν μια βάση δεδομένων για τη διαχείριση των λειτουργιών ελέγχου ενός έργου και εντόπισαν ότι η χρήση τέτοιων συστημάτων είναι ωφέλιμη και για το λόγο αυτό υιοθετούνται και στην παρούσα εργασία.

4.8. Διαχείριση ροής κατασκευής

Η λειτουργία «διαχείριση ροής κατασκευή» αποτελείται από επτά διαδικασίες, τρεις στρατηγικές και τέσσερις λειτουργικές. Οι τρεις στρατηγικές διαδικασίες μπορούν είτε να εκτελεστούν είτε παράλληλα είτε σειριακά, ανάλογα με τις ανάγκες ενός συγκεκριμένου έργου είτε με τις ανάγκες ενός χαρτοφυλακίου έργων, και είναι οι παρακάτω: «καθορισμός επιπέδου ευελιξίας της διαδικασίας κατασκευής», «καθορισμός ορίων στρατηγικής κατασκευής» και «καθορισμός περιορισμών και απαιτήσεων στην κατασκευή». Οι λειτουργικές διαδικασίες εκτελούνται συχνά, ακόμη και σε εβδομαδιαία ή καθημερινή βάση, και είναι σύμφωνα με τους Leblanc et al. (2013) οι παρακάτω: «καθορισμός μακροπρόθεσμου πλάνου εργασίας», «πλάνο εργασιών και πόρων», «εκτέλεση εργασιών» και «μέτρηση απόδοσης διαχείρισης ροής παραγωγής». Οι τρεις πρώτες λειτουργικές διαδικασίες εκτελούνται σειριακά, αλλά η τέταρτη μπορεί να εκτελεστή είτε εν σειρά είτε παράλληλα για κάθε μία από τις άλλες λειτουργικές διαδικασίες.

4.9. Διαχείριση αξιώσεων

Η «διαχείριση αξιώσεων» περιέχει πέντε διαδικασίες, χωρισμένες σε στρατηγικές και λειτουργικές. Από την μία πλευρά οι στρατηγικές διαδικασίες εκτελούνται στην αρχή ενός έργου και ενημερώνονται σε περίπτωση μεγάλων αλλαγών στη στρατηγική της εταιρείας ή στη νομοθεσία. Έτσι διασφαλίζεται η συνέχεια στον τρόπο με τον οποίο γίνεται η διαχείριση αξιώσεων και ακυρώσεων συμβάσεων. Από την άλλη, οι λειτουργικές διαδικασίες εκτελούνται όσο συχνά είναι απαραίτητο. Η βιβλιογραφία αντιμετωπίζει τις αξιώσεις ως ένα στοιχείο με αρνητική κυρίως χροιά και οι συνεντεύξεις συμφωνούν ότι οι σχέσεις ζημιώνονται από τις αξιώσεις και τα έργα καθυστερήσουν. Ενδιαφέρον έχει το γεγονός ότι οι συνεντεύξεις αποκάλυψαν ότι οι αξιώσεις μπορεί, επίσης, να έχουν και θετική επίπτωση στο έργο, για παράδειγμα, οι ανάδοχοι ή οι υπεργολάβοι μπορεί να εντοπίσουν μία ευκαιρία στην πτώση της τιμής ενός χρηματιστηριακού προϊόντος, το οποίο ίσως χρειαστεί σε επόμενο στάδιο του έργου και να υποβάλουν μία αξίωση για νωρίτερη αγορά του. Η βασική υπόθεση πίσω από το μοντέλο αξιώσεων είναι ότι συμπεριφορές στην εφοδιαστική αλυσίδα των κατασκευών βασίζονται στην συνεργασία και στην αμοιβαία εμπιστοσύνη που προκύπτουν σε ένα περιβάλλον συμπράξεων. Στο χώρο της παραγωγικής βιομηχανίας έχει αποδειχθεί ότι σε περιπτώσεις, όπως αυτή της Wal-Mart (Scott et al. 2011), η αμοιβαία συνεργασία είναι σημαντικός παράγοντας στις επιτυχημένες εφοδιαστικές αλυσίδες. Παρά το γεγονός ότι οι εφοδιαστικές αλυσίδες στον κατασκευαστικό κλάδο είναι προσωρινές, οι συνεντεύξεις αποκάλυψαν ότι υπάρχουν μακροχρόνιες σχέσεις και ότι οι αξιώσεις είναι λιγότερο πιθανό να οδηγηθούν σε διενέξεις, εάν έχουν προϋπάρξει καλές συνεργασίες. Επίσης, οι συνεντεύξεις συμφώνησαν με τη βιβλιογραφία όσον αφορά στις επιπτώσεις του οικονομικού κλίματος, επιβεβαιώνοντας ότι σε περιόδους οικονομικής στενότητας, οι συμμετέχοντες σε ένα έργο τείνουν να δείχνουν χαμηλότερα επίπεδα εμπιστοσύνης. Είναι σημαντικό να διατηρούνται σχέσεις που βασίζονται στην εμπιστοσύνη ανάμεσα στα μέρη ενός έργου, αφού η εμπιστοσύνη εμπλουτίζει την αξία της συνολικής υπηρεσίας που παρέχει η εφοδιαστική αλυσίδα των κατασκευών (Xu & Smyth 2015). Για το λόγο αυτό οι καιροσκοπικές συμπεριφορές απορρίπτονται.

5. Συζήτηση

Ο κατασκευαστικό κλάδος έχει πολλές προοπτικές βελτίωσης. Για να εκπληρώσει τις προοπτικές αυτές είναι απαραίτητο να κινηθεί από το παρόν περιβάλλον που χαρακτηρίζεται από εχθρικότητα σε ένα περιβάλλον συνεργατικό το οποίο βασίζεται στις αρχές της θεωρίας διαχείρισης εφοδιαστικών αλυσίδων (Love et al. 2004). Η εφαρμογή πρακτικών που βασίζονται στη θεωρία διαχείρισης εφοδιαστικών αλυσίδων στον κατασκευαστικό κλάδο καθυστέρησε σε σχέση με άλλους κλάδους (Aloini et al. 2012b). Το ιδιαίτερο πλαίσιο των προσωρινών σχέσεων μεταξύ πολλών εταιρειών (Cheng, Law, Bjornsson, Jones & R. Sriram 2010), τα υψηλά επίπεδα αβεβαιότητας και πολυπλοκότητας των παραγωγικών συστημάτων (Fearne & Fowler 2006), η υψηλή επιρροή του πελάτη στο τελικό προϊόν (Pesämaa et al. 2009), ο κατακερματισμός των διαδικασιών (Briscoe & Dainty 2005), και οι δυσκολίες που παρουσιάζει η διαχείριση ευρέων δικτύων προμηθευτών (Briscoe et al. 2001) σε συνδυασμό με το εχθρικό περιβάλλον έχουν καθυστερήσει την υιοθέτηση των αρχών της θεωρίας διαχείρισης εφοδιαστικών αλυσίδων. Στην πράξη, παρά την ανάπτυξη επίσημων και ανεπίσημων συμπράξεων (Briscoe & Dainty 2005), η ανάπτυξη στενότερων σχέσεων και η ολοκλήρωση των διαδικασιών είναι δύσκολο να επιτευχθούν (Bankvall et al. 2010). Η ανάπτυξη και εφαρμογή μεθόδων συνεργατικής εργασίας είναι ανώφελες χωρίς την ενσωμάτωση των υπεργολάβων σε αυτές (Hughes et al. 2006). Για να επιλυθούν τα προβλήματα στην υιοθέτηση της διαχείρισης εφοδιαστικών αλυσίδων είναι απαραίτητη η μελέτη παραμέτρων όπως η σχεσιακή συμπεριφορά, η εμπιστοσύνη και η εστίαση σε βάθος χρόνου (Aloini et al. 2012a). Η επιτυχής εφαρμογή της διαχείρισης εφοδιαστικών αλυσίδων εξαρτάται από τους παρακάτω παράγοντες (σε φθίνουσα σειρά σημαντικότητας): εστίαση στον πελάτη, διαχείριση διαδικασιών, συνεχής βελτίωση, καινοτομία, συμπράξεις με προμηθευτές, ανάπτυξη και συμμετοχή προσωπικού, ηγεσία, συνέπεια στόχων, διοίκηση, οικονομικά, δεξιότητες και τεχνογνωσία, εταιρική κουλτούρα, και θετικές χρηματοροές (Ozols & Fortune 2012). Καθώς η εστίαση στον πελάτη είναι υψηλή στον κλάδο, η διαχείριση διαδικασιών αποτελεί τον πιο σημαντικό παράγοντα για εστίαση. Στη βιβλιογραφία υπάρχει σοβαρή έλλειψη ολιστικών προσεγγίσεων στη διαχείριση εφοδιαστικών αλυσίδων (Barker et al. 2000). Ωστόσο, τέτοιες προσεγγίσεις είναι αυτές που έχουν να προσφέρουν τα περισσότερα πλεονεκτήματα για όλους τους εμπλεκομένους σε ένα δίκτυο (Aloini et al. 2012a).

Σήμερα, οι εταιρείες στοχεύουν να αποκτήσουν δυναμική ευελιξία έτσι ώστε να διαχειρίζονται τις μεταβολές στη ζήτηση και την τεχνολογία εντός των υφιστάμενων εφοδιαστικών αλυσίδων τους, αλλά το μέλλον απαιτεί στροφή στη δομική ευελιξία η οποία εισάγει ευέλικτες επιλογές στο σχεδιασμό των εφοδιαστικών αλυσίδων (Björnfot & Torjussen 2012). Στη βιβλιογραφία έχει εντοπιστεί η συγκεκριμένη ανάγκη και οι ερευνητές κινούνται προς την ανάπτυξη θεωρητικών μοντέλων (κυρίως σε επίπεδο στρατηγικών αποφάσεων) (Aloini et al. 2012b). Η σημασία της μοντελοποίησης διαδικασιών στην επίτευξη της απαιτούμενης διαλειτουργικότητας και ευελιξίας τονίζεται από το ρόλο της διαχείρισης διαδικασιών σε αυτή την προσπάθεια (Gayialis et al. 2015). Οι προσεγγίσεις οι οποίες βασίζονται στις διαδικασίες δίνουν έμφαση στο γεγονός ότι οι διαδικασίες ξεπερνούν τα λειτουργικά «όρια» και είναι απαραίτητη μια από άκρη σε άκρη όψη της διαδικασίας για να υπάρξουν βελτιώσεις, ενώ, αντιθέτως, οι συστηματικές προσεγγίσεις δίνουν έμφαση στο γεγονός ότι οι διαδικασίες δεν είναι αποκομμένες από το περιβάλλον τους και ακολουθούν μια προσέγγιση συνεχούς βελτίωσης (κύκλος του Deming) (Coletta 2011). Και οι δύο προσεγγίσεις αποτελούν χαρακτηριστικά του μοντέλου αναφοράς που αναπτύχθηκε στην παρούσα διατριβή. Επιπλέον, το μοντέλο αναφοράς πληροί τις παρακάτω προϋποθέσεις: ο σχεδιασμός και η διαχείριση των εφοδιαστικών αλυσίδων απαιτεί τον καθορισμό των μερών που συμμετέχουν σε αυτές και τις μεταξύ τους σχέσεις (Cheng, Law, Bjornsson, Jones & R. Sriram 2010), απεικονίζεται με τρόπο γενικό, επαναχρησιμοποιούμενο και εύκολο στην εφαρμογή έτσι ώστε με τις κατάλληλες προσαρμογές να μπορεί να εξειδικευθεί από τους χρήστες (Klingebiel 2008), παρέχει ένα σημείο εκκίνησης βασισμένο σε γνώση που συλλέχθηκε από προηγούμενες προσπάθειες και όχι ένα εργαλείο άμεσα εφαρμοζόμενο (Svensson & Hvolby 2012) και χρησιμοποιεί πρότυπα για την ευθυγράμμιση συστημάτων, τη διασφάλιση της ποιότητας και τη καινοτομία καθώς και για τη μείωση του επιπέδου των διακινδύνευσης (Bankvall et al. 2010; Elliman & Orange 2000; Sánchez-Rodríguez et al. 2006). Επιπροσθέτως, η καινοτομία του μοντέλου αναφοράς είναι η ενοποίηση των διαδικασιών που ανήκουν στη διαχείριση ενός έργου και ενός χαρτοφυλακίου έργων. Έτσι, όπως προτείνουν οι Thunberg και Persson (2014), ενθαρρύνει τις κατασκευαστικές εταιρείες να ξεκινήσουν τη μέτρηση της αποτελεσματικότητας των εφοδιαστικών αλυσίδων τους και να τη συγκρίνουν με αυτή άλλων εταιρειών στον κλάδο.

Τα μοντέλα αναφοράς διαδικασιών προσφέρουν στους χρήστες τους μια κοινή βάση για τη διαχείριση των διαδικασιών τους χωρίς να καθορίζουν πως θα εκτελείται κάθε εργασία χαμηλού επιπέδου ή πως θα διαχειρίζεται κάθε λεπτομέρεια. Τα επιθυμητά αποτελέσματα επιτυγχάνονται πιο αποδοτικά όταν οι δραστηριότητες και οι σχετικοί πόροι διαχειρίζονται συνολικά ως διαδικασία, διεξάγεται η αναγνώριση, κατανόηση και διαχείριση ενός συστήματος διαδικασιών, και προωθείται η συνεχής βελτίωση της απόδοσης της εταιρείας (Coletta 2011). Το μοντέλο αναφοράς που παρουσιάζεται στη συγκεκριμένη διατριβή είναι επαρκώς αφαιρετικό, γεγονός που του επιτρέπει, όπως προτείνουν οι Pajk et al. (2011), να προσαρμόζεται σε υφιστάμενα πληροφοριακά συστήματα τα οποία χρησιμοποιούν οι κατασκευαστικές εταιρείες ή να παρέχει το πλαίσιο για την επιτυχή υιοθέτηση τέτοιων συστημάτων.

Οι συνεντεύξεις που πραγματοποιήθηκαν επιβεβαίωσαν τις πρακτικές που περιγράφονται στο μοντέλο αναφοράς. Επιπλέον, συλλέχθηκαν ενδιαφέροντα δεδομένα στην ανάλυση της κατασκευαστικής βιομηχανίας. Για την καλύτερη κατανόηση των δεδομένων αυτών, χωρίστηκαν σε δεδομένα τα οποία συλλέχθηκαν από μεγάλες κατασκευαστικές και μικρές-μικρομεσαίες κατασκευαστικές εταιρείες. Το μεγαλύτερο μέρος του μοντέλου αναφοράς περιγράφει με ακρίβεια τις πρακτικές οι οποίες ακολουθούνται και στις δύο κατηγορίες. Η σύγκριση των διαφορών ανάμεσα στις πρακτικές των εταιρειών που ανήκουν στις δύο κατηγορίες παρουσιάζει ενδιαφέροντα αποτελέσματα.

6. Συμπεράσματα

Η κατασκευαστική βιομηχανία είναι μία από τις αρχαιότερες. Παρά το γεγονός αυτό, έχει στο σύνολο της καθυστερήσει να προσαρμοστεί στις απαιτήσεις των σύγχρονων πελατών. Τα κύρια αίτια εντοπίζονται στην έλλειψη καινοτομίας και στην προσκόλληση στις παραδοσιακές πρακτικές εφοδιασμού οι οποίες διατηρούν τις κακές σχέσεις ανάμεσα στα μέρη που εμπλέκονται σε ένα κατασκευαστικό έργο. Την τελευταία εικοσαετία έχουν υπάρξει πολλές προσπάθειες να επιλυθούν τα προβλήματα που αντιμετωπίζει ο κλάδος. Αρχικά, οι κυβερνήσεις ήταν αυτές που επέλεξαν να δράσουν, σήμερα όμως η πιο εντατική έρευνα πραγματοποιείται από ακαδημαϊκούς. Η έρευνα εστιάζει στις εφοδιαστικές αλυσίδες των κατασκευαστικών έργων και την ανάλυση των αλληλεπιδράσεων των σχέσεων, των εταιρειών και των έργων από αυτή την οπτική. Την ανάγκη για ένα εργαλείο το οποίο μπορεί να αξιοποιήσει τα αποτελέσματα της έρευνας προς όφελος των επαγγελματιών προσπάθησε να καλύψει αυτή η διατριβή. Το μοντέλο αναφοράς διαδικασιών που δημιουργήθηκε καλύπτει όλες τις πτυχές της εφοδιαστικής αλυσίδας ενός έργου και παρέχει οπτικοποιημένη μεθοδολογία η οποία μπορεί να εφαρμοστεί ανά πάσα στιγμή από κατασκευαστικές εταιρείες που ενδιαφέρονται να μελετήσουν τις πρακτικές που ακολουθούν στις εφοδιαστικές αλυσίδες τους. Οι εννέα λειτουργίες του μοντέλου αναφοράς καλύπτουν όλες τις πτυχές της εφοδιαστικής αλυσίδας με τρόπο χρήσιμο για ακαδημαϊκούς και επαγγελματίες του κλάδου.

Το μοντέλο που δημιουργήθηκε σε αυτή τη διατριβή έχει έναν βασικό περιορισμό. Εστιάζει στις κάθετες σχέσεις της εφοδιαστικής αλυσίδας και δεν μελετά τις οριζόντιες. Αυτό σημαίνει ότι δεν μπορεί να εγγυηθεί παρόμοια αποτελέσματα όταν εφαρμόζεται σε συμπράξεις μεταξύ αναδόχων. Παρά το γεγονός ότι η βιβλιογραφία που μελετήθηκε προέρχεται από όλες τις πλευρές του κόσμου, οι συνεντεύξεις που πραγματοποιήθηκαν περιορίστηκαν σε ειδικούς από την ελληνική κατασκευαστική βιομηχανία. Αν και σε ορισμένες περιπτώσεις οι ειδικοί είχαν διεθνές υπόβαθρο, είναι ριψοκίνδυνος ο ισχυρισμός ότι το μοντέλο μπορεί να εφαρμοστεί αυτούσιο σε όλες τις κατασκευαστικές αγορές ανά τον κόσμο. Ένας δευτερεύων περιορισμός αφορά στην εστίαση στις κύριες αγορές του κατασκευαστικού κλάδου. Εξειδικευμένες αγορές δεν αποτέλεσαν αντικείμενο μελέτης. Επιπλέον, το μοντέλο εστιάζει στους ανάδοχους έργων και δεν εξετάζει τους χειρισμούς των άλλων πλευρών οι οποίοι αντιμετωπίζονται ως «μαύρο κουτί».

Απαιτείται επιπλέον έρευνα με σκοπό τον εμπλουτισμό του μοντέλου αναφοράς με οπτικές διαχείρισης κινδύνων, υποστήριξης αποφάσεων και ανάλυσης οργανωτικής δομής. Η οπτική διαχείρισης κινδύνων μπορεί να παράσχει σημεία στα οποία ελλοχεύουν κίνδυνοι στις διαχειριστικές διαδικασίες, καθώς οι κατασκευαστικές εταιρείες είναι γνωστές για τη διαχείριση κινδύνων σε λειτουργικό επίπεδο. Η υποστήριξη αποφάσεων μπορεί να εφαρμοστεί σε όλο το μοντέλο, ιδιαίτερα όμως στις διαδικασίες διαχείρισης ζήτησης. Η προσθήκη της οργανωτικής οπτικής μπορεί να προσφέρει πληροφορίες για τις ευθύνες σε σχέση με την εφοδιαστική αλυσίδα που αναλογούν σε κάθε θέση του εταιρικού οργανογράμματος. Επιπλέον, πρέπει να εξεταστεί η δυνατότητα εφαρμογής του μοντέλου σε εξειδικευμένες αγορές του κατασκευαστικού κλάδου. Προτείνεται, επίσης, η ολοκλήρωση του μοντέλου αναφοράς με λογισμικά μοντελοποίησης πληροφοριών κατασκευής (BIM) έτσι ώστε να καταστεί δυνατή εκμετάλλευση των δυνατοτήτων που αυτά προσφέρουν. Τέλος, για να είναι δυνατή η απεικόνιση ολόκληρης της κατασκευαστικής βιομηχανίας, θα πρέπει να αναπτυχθούν αντίστοιχα μοντέλα από τις οπτικές του πελάτη και του προμηθευτή και να συνδεθούν με το υφιστάμενο μοντέλο αναφοράς.

Part 2 – Μέρος 2

Dissertation

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1. Introduction

Construction has been on the receiving end of heavy criticism regarding its practices by both academia and governmental institutions. This criticism stems from the comparison with other industries that manage radical changes successfully (Edum-Fotwe, Gibb and Benford-Miller 2004). Baldry (1997) identified that the common perception of the industry's image is that it is: the provider of an unsatisfactory product rarely delivered on time, with limited after-care services, and resulting in excessive and unanticipated costs to consumers; the employer of a disreputable, male-dominated workforce which demonstrates unreliability, low productivity, and limited skill and competence; the operator of outmoded practices utilising low technology to limited effect; the context for corrupt practices which defraud clients and tax-raising authorities; the source of disturbance to everyday personal or corporate lifestyles; the plunderer of resources and the despoiler of open countryside and amenity; the vehicle for unsatisfactory career prospects and excessive employment demands. The main product of the construction industry is the construction project. Dubois and Gadde (2000) describe a project as a temporary network of parties that disperses after finishing the project. This pressures the general contractor to "*develop an enabling structure and an efficient communication system for effective relationship management as part of project management*" (Akintoye, McIntosh and Fitzgerald 2000). The recent shift of client demands from just price to innovation, sustainability and speed has created the need to build closer relationships with subcontractors emphasising the importance of supplier management (Bemelmans, Voordijk and Vos 2012B). This is additional to the shift of responsibilities from clients to prime contractors that has led to the use of integrated contracts (Bemelmans, Voordijk and Vos 2012A). Integration requires the management of inter-organisational flows, processes, systems and actors (Bankvall et al. 2010). But the construction industry is facing problems related to the management of supply chains and, thus, the recommended integration in construction processes cannot be obtained (Briscoe and Dainty 2005).

Planning and managing supply chains requires the proper specification of the participating members and the relationships among them (Cheng, Law, Bjornsson, Jones and R. Sriram 2010). Supply chain management has to take its place in the epicentre of a contractor's total quality objectives (Wong 1999). Contractors must develop an enabling structure and an efficient communication system for effective relationship management as part of project and supply chain management (Taylor and Levitt 2004). The implementation of supply chain management in the construction industry has mainly been tied to collaborative procurement systems, long-term relationships and partnering (Vidalakis, Tookey and Sommerville 2013). But, the existing supply chain management theory does not readily apply in construction and there is a need for the translation of its concepts, practices and techniques into the construction industry (O'Brien, London and Vrijhoef 2004). Paradoxically, focus placed on construction supply networks and operations has been little (Vidalakis, Tookey and Sommerville 2013). For example, logistics has to be integrated in the construction process (Agapiou et al. 1998) in order to obtain potential savings ranging between 10 and 30% in construction costs (Rogers 2005) and combat costs related to quality rectification problems ranging between 3.4 and 6.2% (Thomas et al. 2002). In most cases, a supply chain is described as a network of actors or a network of processes and activities (Harland 1996). But the truth is that supply chain management includes integration of processes and their relative activities and actors (Håkansson and Jahre 2004). There are three views to a supply chain. The first describes the entire industry as a single supply chain and suggests full integration of all activities (Akintoye, McIntosh and Fitzgerald 2000, Proverbs and Holt 2000).

The second focusses on specific relationships in the industry (e.g. builders-merchants) (London, Kenley and Agapiou 1998, Agapiou et al. 1998, Dainty, Briscoe and Millett 2001). The third views the industry as a set of different chains that have to be managed differently (Voordijk, de Haan and Joosten 2000). The view of the supply chain depends on the perspective it is being viewed from. Eccles (1981) views the industry from the perspective of the quasi-firm, an intermediate form between markets and hierarchies which argues that subcontracting develops a set of stable relationships between the general contractor and special trade subcontractors and culminates in a form of relational contracting. Isatto and Formoso (2011) lean towards preferring the Language/Action Perspective that explains how managerial processes occurring in the inter-firm context are coordinated even when little control exists over the sequence and content of the activities. Crowston (1991) and Crowston and Osborn (1998) concluded that the Transaction Cost Theory perspective is not applicable as it assumes that no conflict exists between actors and their goals. The perspective of Transaction Cost Economics criticises the focus on the costs of decomposed transformations alone without accounting for the cost of coordinating (Winch 2006). The perspective of the Theory of Coordination in analysing the inter-firm coordination mainly relates to "the purpose of the supply chain in terms of delivering value to the customer by addressing how tasks are decomposed and assigned to actors, which dependences arise as a consequence of the previous decisions, and how these dependences are managed" (Isatto and Formoso 2011). A process-oriented point of view proposes a supply chain can also be seen as a system of processes or functions (Vidalakis, Tookey and Sommerville 2011). The debate is strong and on-going but this work identifies the lack of a process approach to supply chain relationships in construction.

When Dainty et al. (2001) claimed that "*developing an operational process framework for the implementation of effective supply chain management throughout the value chain clearly is a long term objective*" the field of construction supply chain management was in its infancy. Fifteen years after, the literature has gone a long way in analysing construction supply chains. The aim of this research is to analyse the processes of a typical construction supply chain. The research question is structured as follows: *Can a process reference model for construction supply chains, that can be adopted by any construction company regardless of its size, be created?* Such a model should be well thought-out to satisfy end customer needs (Tommelein, Walsh and Hershauer 2003). The objectives of this dissertation are to: 1) synthesise the requirements and best practices of both small and large companies in the construction market, 2) analyse available sub-models available in the literature, and 3) examine if a collective reference model can be created based on all input. This research is bounded to the analysis of construction supply chain management processes from the contractor's point of view. This means that the client and supplier actions are treated as a black box and transactions between parties are not analysed from a client's or supplier's point of view. Furthermore, it is not the aim of this work to analyse processes below a certain level of abstraction. Expanding analysis to a trivial level poses the risk of dismissing the generalisability of the proposed reference model. As the task of identifying supply chain management processes in the construction industry is daunting on its own, other views included in the generic reference model, such as the risk or decisional views, were not developed in this work. The study does not aim to identify processes describing horizontal transactions of the contractor. Finally, processes and transactions were not studied beyond the immediate client or supplier of the main contractor as they can be adequately described by the existing generic reference model.

The rest of this research is structured as follows. In chapter 2 a literature review is performed in order to provide the main supply chain management concepts and definitions. Then a literature review covering the general background of construction supply chain management is performed. The review does not go deep in all the aspects of construction supply chain management as they are analysed later in the dissertation. Chapter 3 describes the methodology followed in this dissertation and provides a background in process reference modelling, describes the reference model that provided the basis for the creation of the reference model described later in the work, and documents the modelling tool selection. Chapter 4 is the main contribution of this work. Initially, it describes the differences between the generic supply chain process reference model and the construction supply chain process reference model. Then, for each function of the construction supply chain process reference model, a focussed and deep literature review is performed before the description of the functions and processes. Finally, it closes with a brief documentation of interrelationships between the functions of the reference model. Chapter 5 has two functions. The first is the description of how the reference model created attempts to cover the problems identified in the literature through an extensive discussion. The second function is a comparison of practices, related to the reference model, between different sized organisations in the Greek construction industry. Finally, Chapter 6 provides the conclusions of this work, describes the limitations that were identified and provides proposals for further research.

2. Literature review

2.1. Supply chain management

The time when companies produced products and expected customers to adapt their needs to their product characteristics is well and truly gone. Today, companies that want to increase their chances of survival in the highly competitive environment, the global market, have to adapt to their customers' requirements and needs. Power has shifted from the firms to the customers and this has created many and various problems to how firms operate. One of the key elements to meeting customers' requirements is the company's supply chain. Supply chains comprise the flow of materials and components under process, but in many cases include flows of information as in most cases a product is a combination of goods and services (Isatto and Formoso 2011). It is of crucial importance for companies to ensure steady flow of production, quality, and high adaptability to customers' needs.

At this point, it is important to review some of the definitions of a supply chain in the literature. Stevens (1989) described supply chains as "*a system whose constituent parts include material suppliers, production facilities, distribution services and customers, linked together via a feed-forward flow of materials, a feedback flow of information*". Christopher (2011) defined supply chains as "*the network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer*". "Supply chains are linked chains or networks of interrelated tasks designed to best satisfy end-customer needs while rewarding all members of the chain" according to Arbulu et al. (2002). A supply chain, as described by Mentzer et al. (2001), is "*a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from the source to the customer*". APICS (2017) defines the supply chain as "*the global network used to deliver products and services from raw materials to end customers through an engineered flow of information, physical distribution, and cash*". This thesis adopts the definition provided by Mentzer. The difference between the two streams in a supply chain is that downstream flows bear from the supplier to the customer and upstream flows mirror that bearing.

Supply chains are present in every financial sector, from everyday markets like consumer goods, to extremely specialised markets like space shuttles. All supply chains have specific attributes that can be grouped under two categories: 1) topography of a supply chain, and 2) integration and coordination (Meyr and Stadtler 2008). Topography of a supply chain includes the network structure, degree of globalisation, location of decoupling points and major constraints attributes.

Network structure (**Figure 1**) describes the flow of materials that depending on the number of companies in a specific market sector can be either linear or a network (converging, diverging, or both). The degree of globalisation describes the geographic dispersion of a supply chain. It is of high interest as tax, tariffs, currency rates, and legal impediments have to be taken into account when examining supply chains that extend to more than one country.

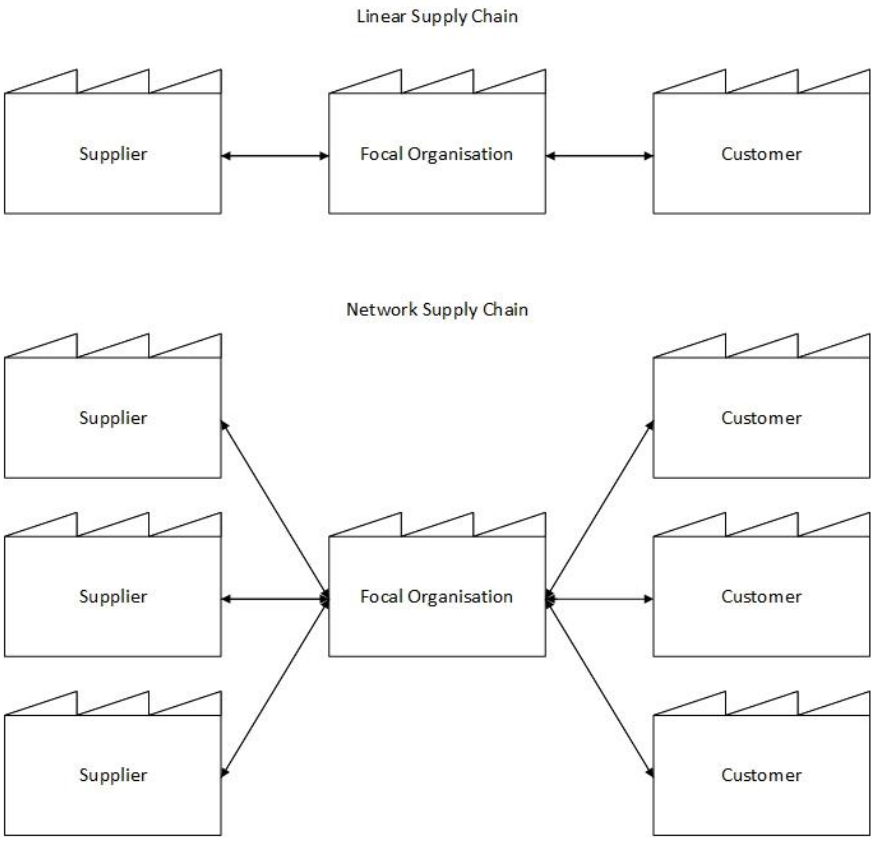

Figure 1: Topographies of supply chains

Decoupling points are specific points in the material flow where products are tied to customer orders (Olhager 2012). The manufacturing process transforms materials and parts to products. Manufacturing processes' can be characterised as engineer-to-order, make-to-order, assemble-to-order, or make-to-stock (**Figure 2**) depending on the point of entry of the customer's order in the material flow.

- Engineer-to-order: Customers take part in the design phase of the product to be manufactured, thus it is tailored to their needs. Also called Design-to-order, contract manufacturing or project manufacturing.
- Make-to-order: Production is initiated when a new customer's order comes in.
- Assemble-to-order: Production of subassemblies waiting for customer order to be assembled in the best possible manner according to the customer's requirements.
- Make-to-stock: Production quantities are determined prior to the point in time when the customer places orders.

Customers that place orders can either be other departments of an organization, or other organisations and/or individuals. Finally, the major constraints attribute represents the bottlenecks of a supply chain as a whole (Meyr and Stadtler 2008).

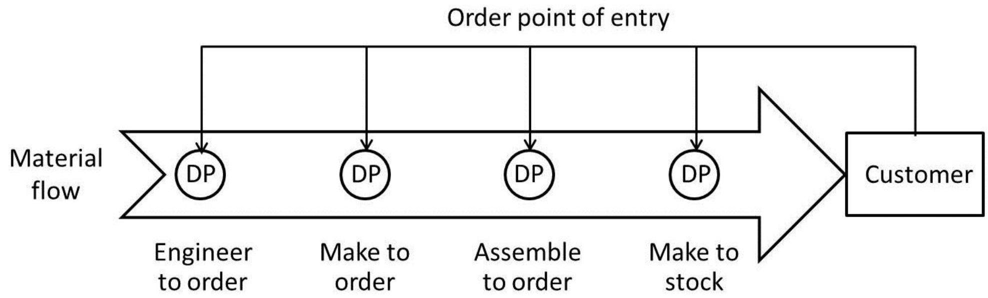

Figure 2: Customer Order Decoupling Point

The second category, integration and coordination include the legal position, balance of power, direction of coordination and type of information exchanged attributes. The legal position attribute categorises supply chains as intra-organisational or inter-organisational depending on transactions being conducted within a legal entity or between separate legal entities (organisations or individuals) respectively. The balance of power attribute applies to inter-organisational supply chains. On the one hand, supply chains with a dominant member have one decision maker, called a focal firm[1]. On the other hand, supply chains comprised of “equal” members have as many decision makers as the participants in the supply chain and are referred to as polycentric supply chains. The direction of coordination attribute is used to describe the information flow. Information flows range from purely vertical to purely horizontal. Vertical information flows comply with hierarchical planning, whereas, horizontal flows exist between two adjacent entities within the supply chain. The management of supply chains has evolved from inventory planning and logistics management to outsourcing strategies including economic issues and risk sharing with suppliers (Williamson 2008).

At this point, a clarification of the difference between the terms Supply Chain and Supply Chain Management is provided. On one hand, the term Supply Chain describes the value creation and delivery (goods/service) process. On the other hand, the term Supply Chain Management describes the importance of managing the dynamics and complexities related to the coordination of activities, tasks, goals and interest in order to optimise process, resource and capability utilisation across a number of organisations working together in the process of value creation and delivery.

Supply-chain management has emerged over the last few decades as an important and strategic area of management decision-making for both profit making and non-profit organisations. Kraljic (1983) was one of the first to argue that a company should view its purchasing activities through a wider lens; that of supply chain management. Since then the research has moved forward a lot. Various subject areas such as purchasing and supply, logistics and transportation, marketing, organisational behaviour, network, strategic management, management information systems and operations management have contributed to the development of supply chain management literature (Chen and Paulraj 2004). Ballou (2004) analyses the path that literature has followed (**Figure 3**) in order to reach, what is considered today, supply chain management.

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[1] In the literature, the term focal organisation/company refers to a company that dominates the supply chain it belongs to. In this essay, the term focal organisation/company will refer to the organisation/company whose processes are under study.

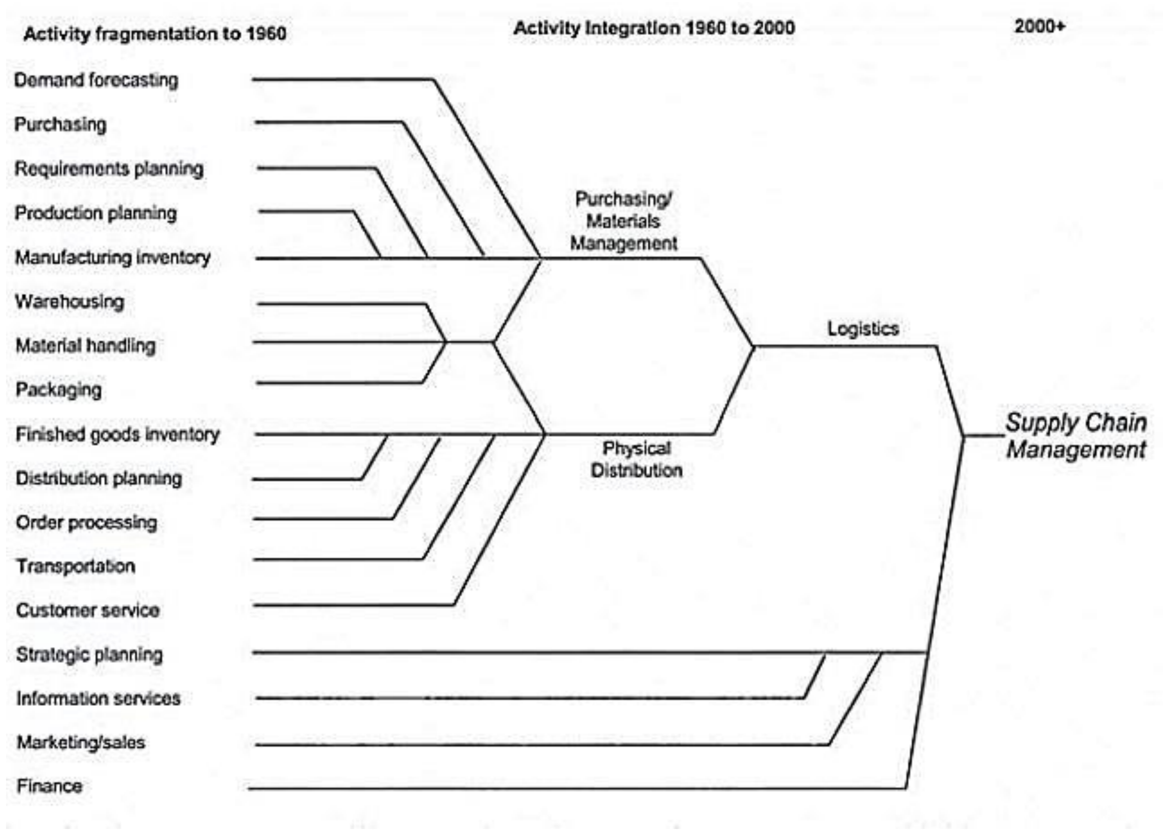

Figure 3: Evolution of logistics toward supply chain management (Ballou 2004, p.9)

Porter (1985) describes the value chain model that has undoubtedly influenced business managers' perspective to adding value to a product, no matter the market they participate. Five primary business operations: inbound logistics; operations; outbound logistics; marketing and sales; and customer service are part of what is called the supply chain.

There have been many efforts in the literature to define supply chain management. The various definitions which have been proposed indicate that supply chain management prescribes organisational restructuring, extended to the achievement of a company-wide collaborative culture (Akintoye, McIntosh and Fitzgerald 2000). In their work, Mentzer et al. (2001) studied their contemporary literature thoroughly and gave their own definition on supply chain management:

- *"Supply chain management is defined as the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole."*

Tan (2001) identified that the term "supply chain management" has multiple meanings and there are many definitions available in the literature. Some of these definitions are related to the management processes, others to the structural organisation of businesses (Harland 1996). Some other definitions for supply chain management existing in the literature include:

- *"Supply chain management, then, endorses a supply chain orientation and involves proactively managing the two-way movement and coordination of goods, services,* *information, and funds (i.e., the various flows) from raw material through end user."* (Monczka et al. 2009)

- *"Supply Chain Management, as we envision, is a novel management philosophy that recognizes that individual businesses no longer compete as solely autonomous units, but rather as supply chains. Therefore, it is an integrated approach to the planning and control of materials, services and information flows that adds value for customers through collaborative relationships among supply chain members."* (Chen and Paulraj 2004)
- *"Supply Chain Management is the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders."* (Lambert, Cooper and Pagh 1998)
- "*The management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole.*" (Christopher 2011)
- "*The task of integrating organisational units along a supply chain and coordinating materials, information and financial flows in order to fulfil customer demand with the aim of improving competitiveness of a supply chain as a whole.*" (Stadtler 2005)
- "*The design, planning, execution, control, and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronising supply with demand, and measuring performance globally.*" (APICS 2017A)
- "*…the process of strategically managing the movement and storage of materials, parts and finished inventory from suppliers, through the firm to customers.*" Johnston ((1995) as seen in Love et al. (2004))
- "*The management of all activities, information, knowledge and financial resources associated with the flow and transformation of goods and services up from the raw materials suppliers, component suppliers and other suppliers in such a way that the expectations of the end users of the company are being met or surpassed.*" (van Weele 2009)
- "*The efficient management of the end-to-end process, which starts with the design of the product or service and ends when it has been consumed and discarded by the consumer.*" (Swaminathan and Tayur 2003)

From the definitions provided, combined with the work of Harland (1996), one can see that there are four uses of the supply chain management term: it describes the internal supply chain integrating business functions involved in material and information flows from inbound to outbound ends; it describes the management of dyadic relationships with immediate suppliers; it describes the management of business spanning from a company's supplier's supplier to the customer's customer; it describes the management of a network of businesses that participate in the provision of a product or service demanded by end customers. Of all the definitions cited above, the definition provided by Mentzer et al. is deemed the most complete, since it covers most aspects of the supply chain, and is thus adopted in this work.

Supplier selection, facility location, and selection of distribution channels are part of a "joined-up thinking" that aims at enabling the achievement of an organisation's marketing objectives (Christopher, Peck and Towill 2006). Supply chain management aims at adding value to the process faster than cost (Lamming 1996, Briscoe, Dainty and Millett 2001). Supply chain management should include practices such as electronic data exchange, quality management, relationship assessments, material flow management, supplier relationships, costs and value (Lamming 1996, Dainty, Briscoe and Millett 2001).

The theory of supply chain management proposes a collaborative environment. In an ideal environment, according to Croom et al. (2000), companies will not seek to achieve cost reductions or profit improvement at the expense of their supply chain partners, but will rather seek to make the supply chain as a whole more competitive. Effective application of information technology to the integration of supply chain activities has the effect of reducing levels of complexity (Power 2005). "*The implementation of supply chain management involves identifying the supply chain members with whom it is critical to link, the processes to be linked with each of these key members, and the type/level of integration that applies to each process link*" (Croxton et al. 2001).

2.2. Construction supply chain management

The construction industry has been present throughout humankind's history, from the establishment of early-organised communities until today. Construction has provided housing from the days of the early cities, but has also offered humanity some wonders such as the ancient Egyptian pyramids, the Greek Parthenon or the Chinese Great Wall in ancient times, to modern buildings like the Empire State Building in the USA or the Burj-al-Arab in the UAE. There is a common truth in all construction projects; there are no two identical projects. Every project is unique in technical, financial and socio-political terms (Segerstedt and Olofsson 2010). The features of the construction industry such as specialised production systems, customer influence, fragmentation, number of stakeholders, type of stakeholders, buyer-supplier relationships, temporary configuration, and change inertia can heavily impact the application of supply chain management theories (Aloini et al. 2012B). Although construction projects share common characteristics in terms of project phases (initial concept, detailed design, construct, commission and own/maintain) and project structures (involving a range of organisations – architects, engineers, contractors, tradesmen and manufacturers) their procurement route often depends on project size, scope, value, complexity and sophistication (Adetola, Goulding and Liyanage 2011). Even in the case of the exact same design, there can be very different conditions in the project environment, its' execution or acceptance by the client. Matthews et al. (2000) observe that each product has its own design and a distinct process of production or erection – the product is, in general, a prototype. In the same line of thought, Hofman et al. (2009) propose that construction projects can be seen as temporary organisations between and within organisations, and therefore standardisation at the multi-project level is difficult as project teams and product designs change from project to project. Matthews et al. (2000) also state that "*unlike manufacturing, the construction process is not continuous and repetitious – and the steps involved are not always identifiable, while process segments, whether they be design or construction based, overlap and impinge on one another in a reciprocally dependent manner producing an outcome that is inherently uncertain*." One of the parameters that change a project's outcome is the supply chain. Shortages in expert craftsmen, materials, disruptions due to unforeseen accidents or extreme natural phenomena, failure to meet financial needs, defaults, bailouts or other factors can affect the construction supply chain from as little as a few days delay to large alterations on the project time schedule or even cancellation of the entire project, regardless of the construction phase.

The construction industry is basically a project based industry (Persson, Bengtsson and Gustad 2010) rife with particularities. Binninger et al. (2016) listed some of the most important characteristics of the construction industry as: construction project execution is divided into specialised trades, clear boundaries between task areas require the provision of warranties, cooperation is time-bound to the end of contracts and scaling effects are very rare, outsourcing work to subcontractors favours short-term project-based thinking and suppresses innovation gains for the main contractor, and global-contracting with functional performance specifications allows poorly considered risk allocation. Eccles (1981) defined construction as "*the erection, maintenance, and repair of immobile structures, the demolition of existing structures, and land development*". According to Akintoye et al. (2000), the construction industry product is in the nature of an investment service where the customer wields great influence on the final product in relation to its physical aspects (dimensions, application of materials, etc.) and the value of logistic parameters (delivery date, project duration, etc.). Based on this, Winch (2003) described three groups of projects: private housing (the only sector of construction that sells to final consumers, rather than intermediate clients), building (meeting the needs of clients for a wide variety of facilities with undemanding technical specifications e.g. public sector housing), and major projects (infrastructure development, highly engineered buildings such as hospitals, and high-rise offices). The selection of a procurement route is highly affected by the prevailing economic climate (Wolstenholme 2009), but construction clients, contractors and suppliers are capable of securing business opportunities via a range of alternative procurement strategies (Tennant and Fernie 2012).

Supply chain relationships in the construction industry are very diverse varying from organisation to organisation, from project to project or even in a particular supply chain (Meng, Sun and Jones 2011). Buyer–supplier relationships in the traditional construction setting can be characterised as a typical market exchange relationship, where, according to Bensaou (1999): "*information exchange between two firms takes place mainly during bidding and contract negotiations*." Suppliers do not get involved in the design of the component and usually manufacture to the buyer's specification. Construction markets are often closed to global competition due to government subsidies, national and local regulations and culture (Segerstedt and Olofsson 2010). Despite the locality of the construction markets, they are still highly fragmented with many SMEs (Small-Medium Enterprises[2]) (Briscoe and Dainty 2005) performing unique activities (Ribeiro and Lopes 2001). This fragmentation can be blamed for the difficulties in developing unified approaches to project delivery and team continuity between main contractors and key supply chain members (Briscoe, Dainty and Millett 2001). According to the most recent data provided by the Eurostat service (Eurostat 2012), 99,91% of all companies operating in the European construction industry in 2007 were SMEs. More recent numbers, at least in the UK, provided by the Cabinet Office (Cabinet Office 2011) report that 99.7% of construction companies in the UK in 2011 are SMEs. In twenty-five out of twenty-seven countries of the EU, SMEs produced, on average, 78,29% of the industry's turnover in 2007 (Eurostat 2012). Unfortunately, there is no available official data that cover the EU after the financial crisis of 2009 struck, and because countries were affected to different extents, it may not be safe to assume that these percentages are still the same. The extremely high percentage of SMEs in the industry

[2] Companies employing up to 250 workers and achieving an annual turnover up to €50m (European Commission 2015).

means that SMEs will most likely represent the majority of companies involved in a construction project. The small size and large number of SMEs requires that main contractors coordinate their operations in order to provide focus and integration of the involved parties (Akintan and Morledge 2013). Each of the functions described by Eccles usually involves a tuple of actors that do not always have the same amount of information coming their way and, most likely, do not belong to the same tier of the project’s supply chain. A problem faced by the construction industry is the tendency of contractors to focus explicitly on their customers’ needs (Saad, Jones and James 2002) and neglect their relationships with their suppliers. This leads to low productivity, cost and time overruns, conflicts caused by bad communication (Aloini et al. 2012B) and required reworks. Many subcontractors do not have the necessary expertise to undertake work satisfactorily which impacts their ability to give their clients the service they require, while, further up the supply chain, many of the undesirable traits common to the main contractor – subcontractor relationship are also common in the subcontractor – sub-subcontractor relationship (Matthews et al. 2000).

The construction value system has a vertical (actors in direct contract with the client) and a horizontal (through which each of those actors fulfils its responsibilities towards the client) dimension (Campagnac, Lin and Winch 2000). The vertical dimension is dubbed the ‘project chain’ by Winch (2001). The horizontal dimension according to Winch (2001) “*consists of either the deployment of in-house resources through an ‘employment relation’, or by sub-contracting through the ‘supply chain’*”. The sum of firms in both the project chain and their supply chains comprises the ‘project coalition’ (Winch 1989, Winch 2001). Materials suppliers and construction contractors share a symbiotic business relationship in this setting (Nicholas and Edwards 2003). Cox and Thompson (1998), as cited in Ribeiro and Lopes (2001), define the construction supply chain as follows: “*A supply chain in construction can be considered as a process of series of activities transforming raw materials into finish products (e.g. roads or buildings) and services (e.g. design or budget) for use by a client irrespective of organization boundaries*”. Construction supply chains share three main characteristics: they are converging (many components and many flows going together into one object), temporary (projects being set up just for one object) and make-to-order (much customisation) (Vrijhoef and Koskela 2000). According to Arbulu et al. (2003), “*construction supply chains should be well thought-out networks of interrelated processes designed to satisfy end- customer needs*”.

A construction supply chain is complex and layered; comprised of the following three key entities: projects, firms, and relationships (Ronchi 2006). Relationships with firms (designers, subcontractors, suppliers) in a project determine a company’s competitive advantage (Ohnuma, Pereira and Cardoso 2000). Construction supply chains are comprised of a large number of key players, including the project client, main contractor, project management consultant, subcontractors, and various suppliers who provide labour, materials, and equipment (Reve and Levitt 1984, Meng 2013, Aloini et al. 2012B). All materials are directed through the supply chain to the construction site where the project is assembled (Briscoe et al. 2004, Love, Irani and Edwards 2004, O’Brien, London and Vrijhoef 2002, Ronchi 2006). According to one approach, in a construction supply chain the client is the end customer, the main contractor, designer and project management consultants are the first tier suppliers, specialist contractors (subcontractors) are the second tier suppliers, and labour, materials and equipment suppliers are the third tier suppliers (Beach, Webster and Campbell 2005).

Subcontractors are directly appointed by the general contractor to deliver works on site; manufacturers and suppliers supply the main elements making up a building; further upstream manufacturers and suppliers of components and materials used in the manufacturing of the main element and so on (Brown et al. 2001). This is not a universal description as different types of relationships may exist at different tiers of the supply chain (Meng 2010). In this work, the construction supply chain (**Figure 4**) is described as seen in the work of Pryke (2009).

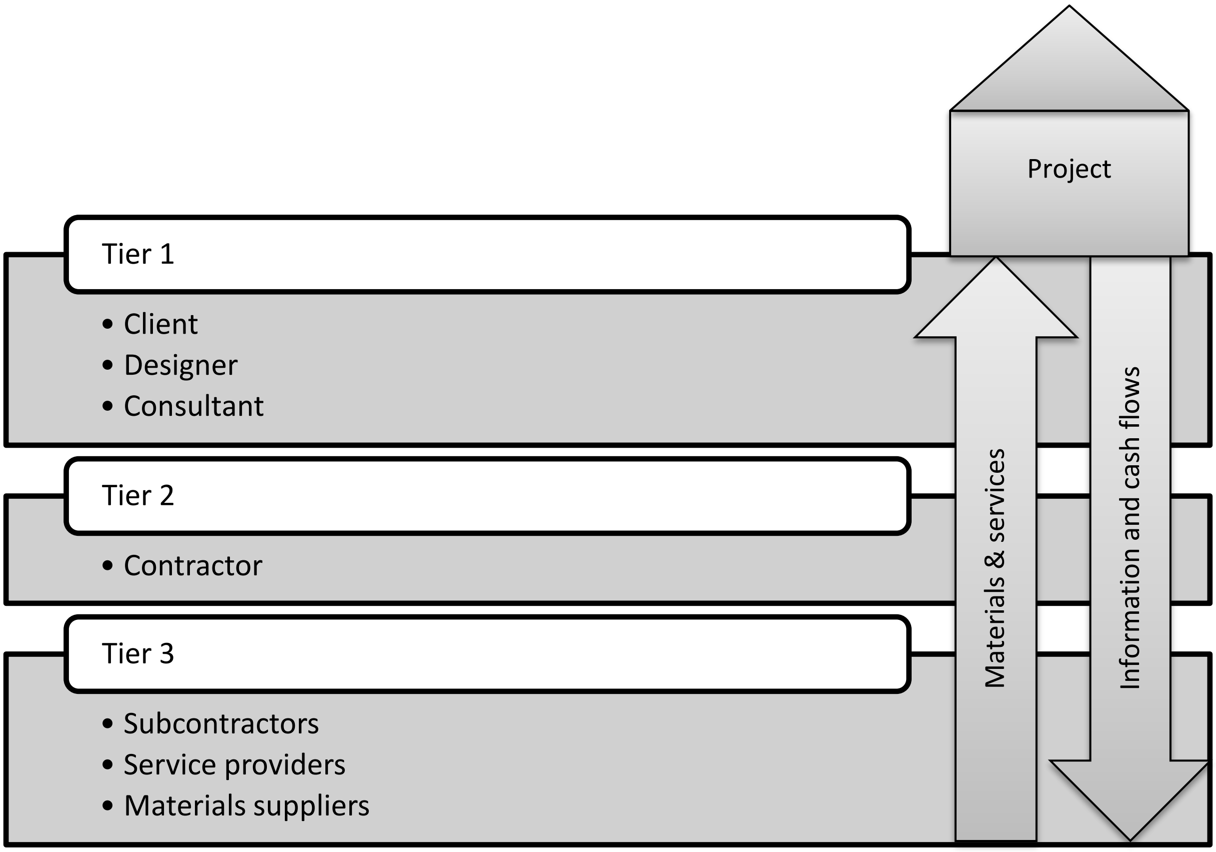

Figure 4: Construction supply chain (adapted from: Pryke 2009, pg.2)

Contractors and engineering consultants relate through the client who appoints the consultant to make day-to-day decisions and their relationship is described in the contract between the client and the contractor (Reve and Levitt 1984). Engineering consultants typically perform the tendering process. Types of relationships along the construction supply chain range from hierarchies to markets, based on the structure of transaction costs (Ronchi 2006). Transaction frequency is low in the client/contractor dyad (Winch 2001). Clients wish to decrease transaction costs and this pushes contractors to develop subcontracting and informal organisational arrangements, in particular semi- integrated forms of production, led by price competition and independence among transacting firms (Ronchi 2006).

The placement of the decoupling point in construction supply chains is not as easy as in manufacturing supply chains. The construction product can be characterised as an Engineer-to-Order product as ETO supply chains produce high-value products on a project basis (Mello, Strandhagen and Alfnes 2015). ETO supply chains serve niche markets, which are characterised by low competition, and customers that are willing to pay a higher price for a perfectly need-fitting product (Stavrulaki and Davis 2010). In addition, companies that participate in ETO supply chains cannot satisfy customer needs at the moment of order placement as they do not keep stock of finished products (Bertrand and Muntslag 1993). As a consequence, they cannot protect their customers from the impact of long lead times (Bertrand and Muntslag 1993, Amaro, Hendry and Kingsman 1999, McGOVERN, Hicks and Earl 1999, Mello, Strandhagen and Alfnes 2015). ETO supply chains are comprised of three phases: tendering (sales/marketing), product development (engineering) and product realisation (production) (Hicks, McGovern and Earl 2000). The coordination of these phases requires specialised coordination mechanisms that are used in situations of limited standardisation and rare repeat orders (Konijnendijk 1994). Winch (2003) proposed that, although ETO describes construction adequately, a further analysis of the industry's particularities called for the following decoupling points: Concept-to-order (the customer enters at the start of the information flow – nothing happens until the client initiates production), Design-to-order (the firm already has a basic product concept, but significant engineering design work is performed for a particular client/customer both pre-bid and post-contract), Make-to-order (there is a fully detailed design which can either be configured to suit a customer's particular requirements or where no additional design work is required, but the materials flow does not start until the customer places an order), and Make-to-forecast (the product is produced for stock and sold after it is manufactured or, sometimes, during manufacture). The Make-to-forecast situation is common in the housing industry.

Supply chain management is a relatively new concept in construction, originating from manufacturing. It is a subject of intense research in the manufacturing discipline since the 1980s. It was introduced to construction through the "rethinking construction" report (Egan 1998) and research on the subject is on the rise. Despite the amount of research in manufacturing, the results do not readily translate to construction supply chains. The construction industry is characterised by temporary supply chains resulting in fragmentation and instability (Persson, Bengtsson and Gustad 2010). Construction markets are often closed to global competition due to government subsidies, national and local regulations and culture (Segerstedt and Olofsson 2010). Despite the locality of the construction markets, they are still highly fragmented with many SMEs (Small-Medium Enterprises) (Briscoe and Dainty 2005) performing unique activities (Ribeiro and Lopes 2001). Matthews et al. (2000) find that the increase in complexity, the over-supply of specialist firms, and the declining construction output (maturity of the market) has aided the cultivation of an adversarial atmosphere that has had a negative effect on main contractor - subcontractor relationships. Competition results in a fragmented system of economically independent units, each attempting to maximise its benefit, to the detriment of the co-operation required of a technically interdependent system (Rooke, Seymour and Fellows 2003).

The client–supplier relationship is portrayed by Saad et al. (2002) and Fernie and Thorpe (2007) as critical in construction supply chain management. The client–main contractor relationship is regarded as the main relationship in a construction supply chain (Cox and Thompson 1997). As a result, supply chain relationships distinguish one construction supply chain from another (Meng 2012). Supply chain relationships in construction are very diverse, ranging from the traditionally adversarial, to the short-term collaborative, and to the long-term collaborative relationships. The traditional adversarial nature of construction is heavily criticised in the literature and a proposal for collaboration in many levels between supply chain actors is promoted. Meng (2012) states that deterioration of supply chain relationships is a major reason for the occurrence of poor performance such as time delays, cost overruns and quality defects. This dissertation considers the client - contractor - subcontractor tiers (Figure 4) as the main construction supply chain under study as all other tiers upstream the subcontractor (e.g. chemicals industry) can be described by other supply chain models.

Dominant thinking in the construction sector lacks an understanding of contextual factors like Porter's five forces (Cox and Ireland 2002). Specifically, according to Suzuki (1999), intensity of rivalry is high, substitutes is low, supplier power is low, buyer power is high and new entrants is average. Because of the localisation of construction markets, the competitive environment tends to be weak, although this depends on the nature of the construction project. For example, a large infrastructure project will be tendered and only a few large enterprises will meet the criteria of the tendering process and bid for the project, thus not allowing competition to provide the lowest possible costs for the client. On the other hand, competition between SMEs for a residence renovation could be fierce and drives prices so low that the profit margins are minimal. Hofman et al. (2009) point out that most construction companies operate in such a decentralised network of suppliers and customers, and draw on the production capacity of various external suppliers as a lead firm, a systems architect, and introduce design rules for standardised product modules. The project-based nature of the construction industry and the unique site conditions play an important role in this. The customer of a construction company is often "separated"; this means the first tier customer to the construction company is often an agent for the second tier customer; and the real consumer of the product (e.g. the tenant of the flat) is still not known (Segerstedt and Olofsson 2010). This creates the problems of customer equivocality and uncertainty that affect the quality of the brief and hamper the contractors decision process regarding the degree of production flexibility (Engström, Sardén and Stehn 2009). Matthews et al. (2000) find that the increase in complexity, the over-supply of specialist firms, and the declining construction output (maturity of the market) has aided the cultivation of an adversarial atmosphere that has had a negative effect on main contractor - subcontractor relationships. Traditional arms-length agreements are governed by market, hierarchical or hybrid governance modes (Manu et al. 2011). The project delivery process is largely disconnected and this complicates main contractors coordination efforts as there is still a high focus on self-interests (Akintan and Morledge 2013). This disconnection refers to the common practice of separating design and production processes (Bankvall et al. 2010). Parties are all involved at different phases of a project and each of them has its own work activities, technologies and experience (Chen and Chen 2007) that can perplex relationships. The complexity of relationships in a project leads to confrontations and disputes that require careful management in order to prevent them from adversely affecting the project (Larson 1995, Cheng and Li 2001, Kanji and Wong 1998, Lee et al. 2009).

Supply and demand issues of labour forces in the construction sector were first addressed in the Business Roundtable report (Blough 1983) along with inefficient information flows. Despite the problems stated in the report, research in these directions and supply chain management in construction, in general, was slow to take off. In the mid-nineties two reports, one by Latham (1994) proposing partnering to the UK construction industry, and one by Egan (1998) introducing supply chain management to the construction industry, would set the field for construction supply chain management theorists. Five key drivers for change were defined by the Egan report: committed leadership, a focus on the customer, integrated processes and teams, a quality driven agenda, and commitment to people (Wamelink, Stoffele and Aalst 2002). Despite the focus of the Egan report on the UK construction industry, these change drivers were adopted by other governments or institutions in the world such as the Dutch construction industry (Boes and Dorée 2013), and the Australian (Dulaimi et al. 2002) and Hong-Kong (Tan et al. 2015) governments which initiated their own studies. Furthermore, academia also adopted the supply chain initiative in the construction industry, with key works from Vrijhoef and Koskela (2000), Akintoye and Main (2007), Eriksson (2010b), Saad et al. (2002), and Gadde and Dubois (2010) opening new horizons in improvement of internal and external efficiency, reduction of waste, and value adding along the entire supply chain.

Latham suggested that the construction industry should adopt the concept of partnering. Burtonshaw-Gunn and Ritchie (2004) point out that the most quoted and probably universally accepted definition for partnering is that from the National Economic Development Council which states that "*partnering is a long term commitment between two or more organisations for the purpose of achieving specific business objectives by maximising the effectiveness of each participant's resources. The relationship is based upon trust, dedication to common goals and an understanding of each other's individual expectations and values.*" (NEDC (1991) as seen in Bemelmans et al. (2012)). Naoum (2003) described partnering as a "*concept which provides a framework for the establishment of mutual objectives among the building team with an attempt to reach an agreed dispute resolution procedure as well as encouraging the principle of continuous improvement*". It contrasts the typical subcontracting practice where a supplier just performs some aspect of the contractor's work on a project (Arditi and Chotibhongs 2005). It is a contractual arrangement between the two parties either for a specific length of time or for an indefinite period (Latham 1994). A partnering framework, be it vertical or horizontal, once established can provide visibility to the project participants, formalise the agreed expectations surrounding mutual objectives, establish problem resolution mechanisms, and ensure all parties have a commitment to continuous improvement (Burtonshaw-Gunn and Ritchie 2004). Partnering must instil trust, co-operation, and teamwork, thus warranting the participants to focus upon project objectives. It is a management method that aims to align organisations in order to reach a mutual mission and vision, improve safety, build quality teams, reap economic benefits, improve working relationships and prevent litigation. In their study, Bresnen and Marshall (2000) identified the following opportunities emerging from successful partnering: potential net benefits that stem from increased productivity and reduced costs; reduced project times stemming from early supplier involvement and team integration; improved quality through focusing on learning and continuous improvement; improved client satisfaction and enhanced responsiveness to changing conditions; greater stability that helps companies effectively deploy resources. Benefits from partnering do not appear on a projects hard factors (e.g. financial data), they mainly cover a number of 'softer' factors including enhanced team-working, identifying mutual objectives, reduced risk and more efficient problem solving, all of which may indirectly influence project cost (Burtonshaw-Gunn and Ritchie 2004). However, as Matthews et al. (2000) point out, most work undertaken in construction partnering has been largely main contractor-client based, with little or no mention of adopting partnering with subcontractors. This is an important omission since the contributions of subcontractors to the total construction process can account for as much as 90% of the total value of a construction project (Nobbs (1993) as cited by Matthews et al. (2000)). Nobbs also acknowledged that the increased involvement of subcontractors in the shift away from the traditional craft-base has led to a greater reliance on increasingly sophisticated technological based products, which, in turn, has led to main contractors concentrating their efforts on managing site operations rather than employing direct labour to undertake construction work. Successful partnering is dependent upon aspects such as communication, teamwork, understanding of each other needs, trust and openness, establishment and communication of a conflict resolution strategy, willingness to share resources, clear definition of responsibilities, commitment to a win-win attitude, regular monitoring of the partnering process, and early involvement in the process (Eriksson 2010, Chan, Chan and Ho 2003).

Fernie and Thorpe (2007) assert that the current discourse of change proposes the need for a journey away from adversarial attitudes towards enlightened co-operative relations and appears to demonise adversarial opportunistic behaviour, which they characterise as bad, over cooperative and collaborative behaviour, which they characterise as good. This behaviour could lead the client and contractor to enter into a specific and formal partnering agreement. In order for this to happen, strong institutional partnering norms are a prerequisite (Phua 2006). The parties agree to work together, in a relationship of trust, to achieve specific primary objectives by maximising the effectiveness of each participant's resources and expertise. This agreement might not be limited to a particular project (Latham 1994). Burtonshaw-Gunn and Ritchie (2004) describe three groups of principle barriers inhibiting the adoption of partnering: corporate culture, the traditional client-contractor roles and the time required to develop the necessary relationships. Chan et al. (2004) added lack of commitment and support from senior management to the barriers. Meng (2010) indicated that these factors lead to both adversarial relationships and partnering failure.

At this point, it is important to define the terms "contract" and "arrangement". A contract is a legal agreement, usually between two companies or between an employer and employee, which involves doing work for a stated sum of money (Collins Online Dictionary 2015). Arrangements are agreements that made with someone to do something (Collins Online Dictionary 2015). Popular types of partnering contracts are described in **Table 1**.

Ulrich and Ellison (2005) describe four options in dividing design and production tasks between supply chain partners: internalise development and production; internalise development and outsource production; outsource development and internalise production; or outsource both development and production. In a non-integrated or specialised supply chain structure, both development and production tasks are outsourced to external suppliers (Hofman, Voordijk and Halman 2009). This practice of concession contracts is widely used to deliver economic infrastructure projects (Kumaraswamy and Zhang 2001).

Contracts describe the arrangements between the agreeing parties. They provide clients with the right and obligation to supervise and monitor the work of a construction contractor (Reve and Levitt 1984). Arrangements of different types are used, depending on the intention of the clients. The main type of arrangement is the Build, Operate and Transfer (BOT) (Palaneeswaran, Kumaraswamy and Zhang 2001), but there are many alterations as described in **Table 2**.

Table 1: Types of partnering contracts

Types of partnering contracts	Short description
Public Private Partnership (PPP)	Public Private Partnership (PPP) emerged from the idea of allowing private firms to finance projects or public sector infrastructure. Since 1992, PPP appears to have become increasingly popular worldwide as a vehicle for delivering large public infrastructure projects (Adetola, Goulding and Liyanage 2011). PPP has been defined differently by many authors and Boeuf (2003) concludes that there is no one-size-fits-all definition of PPP.
Project Partnering Contract (PPC2000)	PPC2000 is a published form of multi-party contract for procurement of capital projects in any jurisdiction. It is based on heads of terms devised by the cross industry Construction Industry Council Partnering Taskforce and was drafted by the UK and International law firm Trowers & Hamlins. Sir John Egan launched PPC2000 in September 2000. The key differences between PPC2000 and other published contract forms are that: it integrates the entire Project Team under a single multi-party contract, and it covers the entire duration of the procurement process. (Saunders and Mosey 2005)
Joint Contract Tribunal (JCT)	The JCT originally comprised a drafting committee made up of individuals from various sectors of the industry. It included contractors, consultants, and representatives of employers. The Forms were, therefore, drafted by the committee and developed slowly over a period of time. JCT Forms in the main are lump sum contracts. In other words, the contract sum is fixed, subject to the correction of any errors and adjustment to the scope of the works by way of a change order. Initially, JCT produced prime cost contracts for cost plus work, as well as management contracting forms and standard forms for works package contractors. (Gould 2005)
New Engineering Contract (NEC)	The New Engineering Contract, or NEC Engineering and Construction Contract is a formalised system created by the Institution of Civil Engineers that guides the drafting of documents on civil engineering and construction projects for the purpose of obtaining tenders, awarding and administering contracts (Brook 2004). As such they legally define the responsibilities and duties of Employers and Contractors in the Works Information (Gerrard 2005).
Bespoke agreements	Bespoke agreements are contracts commissioned to particular specifications made by the clients. Non-standard bespoke contracts create a large number of legal issues throughout drafting, review and negotiation (Mills 2015).

Table 2: Types of arrangements (Palaneeswaran, Kumaraswamy and Zhang 2001, Kumaraswamy and Zhang 2001, Adetola, Goulding and Liyanage 2011, Meng 2010)

Types of arrangements	Description
Design, Bid and Build arrangement (DBB)	The public sector uses this traditional project delivery method. The client retains a designer/architect to produce a facility to meet specified needs. Then, a tendering process takes place where a concessionaire is selected, based on the clients specified criteria (usually financial), to build the specified facility.
Build, Operate and Transfer arrangement (BOT)	A BOT project can be described as a project based on the granting of a concession by a client to a consortium or concessionaire who is required to ‘Build’ (including financing, design, managing project implementation, carrying out project procurement, as well as construction), ‘Operate’ (including managing and operating the facility or plant, carrying out maintenance etc., delivering product/service, and receiving payments to repay the financing and

Types of arrangements	Description
	investment costs, and to make a margin of profit), and to 'Transfer' the facility or plant in operational condition and at no cost to the client at the end of the concession period.
Build, Operate and Deliver arrangement (BOD)	A different term for BOT.
Build, Operate and Lease arrangement (BOL)	The concessionaire builds, operates, and leases out the facility to the client for use. There is no transfer.
Build, Own, Operate and Maintain arrangement (BOOM)	A different term for BOT.
Build, Own, Operate and Transfer arrangement (BOOT)	The client cedes ownership rights to a consortium or concessionaire who is required to 'Build', 'Own', 'Operate' and 'Transfer' the facility or plant in operational condition and at no cost to the client at the end of the concession period.
Build, Own, Operate, Subsidise and Transfer arrangement (BOOST)	The client cedes ownership rights to a consortium or concessionaire just as in BOOT, but the client also subsidises the concessionaire during the concession period in order to obtain additional social benefits from the facility.
Build, Own and Operate arrangement (BOO)	The client cedes ownership just as in BOOT but the facility is never transferred to the client.
Build, Own, Operate, Transfer and Train arrangement (BOOTT)	The client cedes ownership just as in BOOT and the concessionaire has the additional obligation to train employees of the client for post-transfer management.
Build, Rent and Transfer arrangement (BRT)	This arrangement is similar to the BOT arrangement, but the concessionaire can rent the facility prior to its transfer to the client.
Design, Build, Finance and Operate arrangement (DBFO)	This is an arrangement where the concessionaire is required to 'Design', 'Build', 'Finance' and 'Operate' a facility. The 'Transfer' to the client requirement is not clearly stated.
Design, Build, Finance and Maintain arrangement (DBFM)	This is an arrangement where the concessionaire is required to 'Design', 'Build', 'Finance' and 'Maintain' a facility. The 'Transfer' to the client requirement is not specifically stated.
Design, Build, Operate and Transfer arrangement (DBOT)	This is a BOT arrangement with the addition that the 'Design' obligation is specifically stated.
Design and Build arrangement (DB)	In this type of arrangement, the client requires from the concessionaire to 'Design' and 'Build' a facility. The 'Transfer' to the client requirement is not specifically stated.
Design, Build and Maintain arrangement (DBM)	In this type of arrangement, the client requires from the concessionaire to 'Design', 'Build' and 'Maintain' a facility. The 'Transfer' to the client requirement is not specifically stated.
Design, Build and Operate arrangement (DBO)	In this type of arrangement, the client requires from the concessionaire to 'Design', 'Build' and 'Operate' a facility. The 'Transfer' to the client requirement is not specifically stated.
Finance, Build, Own, Operate and Transfer arrangement (FBOOT)	This is a BOOT arrangement with the addition that the 'Finance' obligation is specifically stated.
Refurbish, Operate and Transfer arrangement (ROT)	This is the equivalent of the BOT arrangement for existing facilities refurbishment.

Despite the benefits that derive for both sides in partnerships, many partnership projects were not delivered. Some of the documented reasons to these failures are: wide gaps between public and private sector expectations, lack of clear government objectives and commitment, complex decision making, poorly defined sector policies, inadequate legal/regulatory frameworks, poor risk management, low credibility of government policies, inadequate domestic capital markets, lack of mechanisms to attract long-term finance from private sources at affordable rates, poor transparency and lack of competition (Asian Business 1996). Lack of private participants with the capacity to do business also seems to be a significant barrier, especially to the success of public private collaboration (Henderson and McGloin 2004). In their study of partnership adoption, Gadde and Dubois (2010) conclude that the expectations of a rapid movement towards strategic partnerships were unrealistic, despite the obvious benefits to all participants, since it would require major modifications of basic conditions in the construction sector established over a long time.

Despite the barriers to the implementation of partnering in construction, parts of the industry have started moving toward the adoption of supply chain management relationships to increase quality and efficiency following the suggestions of the Egan report. More informed private-sector clients who were early adopters of partnering in the early 1990s are pioneers in this movement, as they attempt to both increase the degree of collaboration that exists between their preferred consultants and contractors and to extend this approach downstream to include key subcontractors and suppliers. Some public-sector clients are also building the purchaser-supplier relationships associated with supply chain management (Saad, Jones and James 2002). Despite the aforementioned efforts, the existing manufacturing research in supply chain management, while useful, does not readily translate to a construction environment given the transient nature of production in construction projects (O'Brien 1999).

In the literature, in contrast to manufacturing supply chain management, the field of construction supply chain management is still in its infancy and there has been some controversy about the existence of a need to study construction management in this direction, although this is only a very small fraction of the literature (Winch 2003, Green, Fernie and Weller 2005, Fearne and Fowler 2006). Just as generic supply chain management theorists have not reached to a consensus on the definition of the field, construction supply chain management theorists have trouble agreeing on a definition for the field. Some of the definitions provided by authors follow below:

- "*The task of integrating organizational units along a supply chain, including the construction site and subcontractors, and coordinating materials, information and financial flows with the project site plan in order to fulfil the (ultimate) customer demands*" (Persson, Bengtsson and Gustad 2010).
- *"It is the coordination and the integration of key construction business both processes and members involved in construction supply chain, extending traditional intra-enterprise activities in a management philosophy by bringing together partners who have the common goals of optimization and efficiency so establishing long-term, win/win, and cooperative relationships between stakeholders in a systemic perspective"* (Aloini et al. 2012B).
- "*The construction supply chain could be interpreted as an "extended enterprise" in which all firms (project developer, architect, engineering firm, contractor, subcontractors, suppliers) virtually operate as "business units" representing the "business functions" (marketing, design, engineering, components manufacture, supply, assembly, delivery) of a "factory without walls" that acts as a collaborative network of organizational units, regardless of location and regardless who owns them.*" (Cooper & Rousseau (1999) as cited by Voordijk & Vrijhoef (2003))

Construction supply chain management offers new approaches to reduce the cost and increase the reliability and speed of construction (O'Brien 1999). Nevertheless, supply chain management implementation in the construction industry is characterised as scattered and partial (Gadde and Dubois 2010). Benefits of supply chain management adoption recorded in the literature by Papadopoulos et al. (2016) include: reduced real costs, margins maintenance, incentive to remove waste from the construction process, competitive advantages, greater certainty of out-turn costs, delivery of better underlying value to the client, on time delivery, productivity improvement, value creation, additional repeat business with key clients, greater confidence in longer-term planning, and better relationships between parties.

As it is happening in other industries, the competition in the next decade is expected to be among different supply chains and not among individual companies in the construction business (Sharma 2012). Pan et al. (2011) underline that "*without good SCM in construction project management there will be excessive costs, inefficient information flow, and inefficient communication between project stakeholders*". Centrally co-ordinated supply chains, besides minimising transaction costs, also enhance the transfer of expertise and systematic feedback on planning, design, construction and maintenance between parties, and ultimately add towards joint value maximisation (Voordijk and Vrijhoef 2003). Whereas current construction methods tend to support the fragmentation that plagues construction, supply chain management promises an engineering basis to design, plan, and manage construction projects in a collaborative manner (O'Brien 1999). Depending on the focus of management on the supply chain, the construction site, or both, there are four major roles of supply chain management in construction: focus on the impact of the supply chain on site activities, focus on the supply chain with the goal of reducing logistics, lead-time and inventory costs, focus on transferring activities from the site to earlier stages of the supply chain, and focus on the integrated management and improvement of the supply chain and site production (Vrijhoef and Koskela 2000). These roles are not mutually exclusive and are often used jointly (Papadopoulos et al. 2016).

There have been many efforts by construction companies to adopt supply chain management but most of them have failed. Analysing the literature provides plenty reasons for these failures. Briscoe and Dainty (2005) identified six main reasons for the failure of adopting supply chain management in construction: lack of trust between partners at different tiers, lack of other actors systems resulting in misalignment of systems and processes, coordination driven mainly through project management techniques and alignment of Information and Communication Technology (ICT) systems, vested interests, complexity of each project in terms of actors involved, and, in most cases, lack of development of partner relationship at the earliest point of a project. Elsewhere in the literature, lack of understanding of basic supply chain management concepts (Fernie and Thorpe 2007, Saad, Jones and James 2002) is mentioned as a major issue. Fernie and Thorpe (2007) believe that the diversity of definitions for supply chain management in the literature has an impact on successful adoption in construction companies. Saad et al. (2002) suggest that construction companies are not aware of their need for external support in their efforts to adopt supply chain management and, thus, their chances of success are limited. Discontinuous workloads and demand (Segerstedt and Olofsson 2010) are also to be blamed for failed attempts. Furthermore, the entrapment in strict partnership concepts and practices does not allow the full exploitation provided by supply chain management theory (Briscoe and Dainty 2005, Saad, Jones and James 2002, Fernie and Thorpe 2007).

Thus, the adopting organisations (mainly the general contractor and its subcontractors) have to deal with managerial, organisational, relational and technological issues which must be appropriately managed in order to effectively apply supply chain management principles, models and techniques and to overcome the barriers to construction supply chain application

(Palaneeswaran et al. 2003). One important issue of extended enterprises and virtual corporations in the construction supply chain, highlighted by Voordijk and Vrijhoef (2003), is the division, allocation and co-ordination of operations, specialised tasks and firms. This is amplified in the construction industry because of the high share of SMEs. Intensive cooperation, coordination and communication in the network of firms is required, where, as Burtonshaw-Gunn and Ritchie (2004) propose, successful client and main contractor relationships can result in ensuring effectiveness and efficiency across all dimensions of the total supply chain, both horizontally and vertically.

The most important factors in successful relationships are communication, trust and collaboration. Open and effective communication is reflected by transparency, sharing information and learning (Palaneeswaran et al. 2003, Chen and Chen 2007). Information sharing is described by Hsu et al. (2008) as the integration of information systems, decision systems, and business processes used to conduct information searches, manage business operations, monitor business details and perform other business activities. Communication is facilitated through information technologies (Alshawi and Ingirige 2003, Benton and McHenry 2010). Moving to trust, Sako (1992) (according to Meng (2010)) identified three types of trust: contractual trust, competence trust and goodwill trust. Trust can lead to eased negotiation, reduced conflicts and enhanced performance in exchange relationships (Hartmann and Caerteling 2010). Trust is influenced by and influences asset specificity, uncertainty, frequency of transactions, task complexity, and difficulty of performance measurement (Poppo and Zenger 2002). Performance measurement is, unfortunately, connected to suspicion of one party in an adversarial environment (Larson 1997). Finally, collaboration is defined by Simatupang et al. (2004) as "*two or more independent firms jointly working to align their supply chain processes so as to create value to end customers and stakeholders with greater success than acting alone*". Meng (2013) reports that supply chain collaboration trends are characterised by: wide recognition of the importance of supply chain collaboration in the industry; support from the UK government; wide acceptance of collaborative working as a management strategy; and an unbalance of relationship development. In fact, the main idea behind collaboration is integration of supply chain processes in order to provide improved customer value (Bankvall et al. 2010). An example of such approaches is the CM-GC method where the owner contracts with a construction manager (CM) early in design development who, during the construction phase, becomes the general contractor (GC) (Alleman et al. 2017). Effective collaboration is characterised by the following distinct perspectives: shared team responsibility, execution focused team, joint capability and structure, and senior leadership pairing (Suprapto et al. 2015). Collaboration is a prerequisite for the removal of legal and organisational hindrance and the enabling of greater innovation levels (Dulaimi et al. 2002). The following aspects of collaboration were identified as important or critical by Shelbourn et al. (2007): a set of communication procedures that all stakeholders should use in the collaboration, standards that facilitate interoperability between systems, procedures to promote trust in the collaboration, processes that enable participants to agree to a common vision and priorities for the collaboration, processes that enable managers to engage and commit key stakeholders, tools that measure business benefits of collaborative working, agreed and well defined terminology, performance measures that enable the success of the collaboration to be measured, standard technologies (off the shelf) that may be able to fulfil the needs of the collaboration, and tools that assess the effectiveness of collaborative working techniques for any process.

2.3. Literature gap

The construction industry can support financial growth due to its multiplier effect on the economy (Akintoye and Skitmore 1994), but it is criticised for lack of efficiency and innovation of its operations when compared to other industries (Edum-Fotwe, Gibb and Benford-Miller 2004, Leblanc et al. 2013, Khanzode et al. 2006). Although there is an increasing interest for research in construction supply chain management, one can notice a clear trend in publications. That is the division of, on the one hand, management of product and service flows to the construction site (supply chain), and on the other hand, the management of construction site logistics (Persson, Bengtsson and Gustad 2010). There is some progress noted related to the adoption of technology and tools, but there were no big improvements in the industry's productivity (Abdel-Wahab and Vogl 2011, Fulford and Standing 2014, van Lith et al. 2015). Barker et al. (2000) and Love et al. (2004) reported a clear dearth in holistic supply chain management approaches in construction projects. The adoption of supply chain management in construction, from an operational viewpoint, has been largely based on lean and agile construction concepts (Vidalakis, Tookey and Sommerville 2013). Boes and Holmen (2003) underline that these concepts aim primarily at "*changing the relations between client and contractors, but they may also change the relations between contractors and their suppliers, which may be(come) responsible for the design and/or engineering of a specific part of the construction*". Today, common practice relates to the symptomatic treatment of problems in construction supply chains but these do not provide predictability, do not clearly define possible branching's and actions, and do not clearly describe areas of responsibility (Kovács 2016). Vollman et al. (1998) (as seen in Love et al. (2004)) have suggested that construction SCM should be seen as an integrated set of practices aimed at managing and co-ordinating the entire chain from raw materials to end customers. Cooperation initiatives (e.g. Latham 1994; Egan 1998; Egan 2002) and strategies (Robeiro and Love 2003, Love, Irani and Edwards 2004, MacLeamy 2012, Nag, Han and Yao 2014) in construction depict the industry's desire to move away from adversarial relationships and poor performance (Anvuur and Kumaraswamy 2006).

The study by Arbulu et al. (2002) showed that construction supply chains lend themselves to being mapped by process models. In general, the nature of supply chain processes with inter-organisational activities, involving different enterprises, calls for their design, analysis, control and evaluation in a well-designed and structured manner (Panayiotou et al. 2010). The restructuring of construction supply chain processes is considered the most promising opportunity to achieve lasting cost reductions (Lönngren, Rosenkranz and Kolbe 2010). Process models can provide comprehensive understanding of processes and analyse and integrate businesses through their processes (Aguilar-Savén 2004). Process models are placed in the epicentre as a means for achieving the required business process interoperability and agility in dynamic supply chains (Ponis 2005). Integrated coordination of all processes and operations is a prerequisite for a successful supply chain management in the construction industry (Lönngren, Rosenkranz and Kolbe 2010). There is a clear gap in the construction literature regarding process reference models for the construction supply chain, despite the fact that the use of the SCOR model has provided benefits in specific cases (Persson, Bengtsson and Gustad 2010). This work aims to provide the literature with a complete process reference model built specifically for the particularities of construction supply chains. Currently, attempts to adopt reference models that have either been developed by governments or academics, have failed in the construction industry since there is still a need to convince practitioners of their benefits related to understanding, consistency and process efficiency and educate them on their practical implementation (Jones and Sharp 2007). In addition, the use of process description languages in the handling of construction processes is scattered (Kovács 2016). Summarising, supply chain management assumptions are neither widespread nor wholly adopted by organisations in the construction industry (Fernie and Tennant 2013, Arantes, Ferreira and Costa 2015). It is the aim of this work to propose a process reference model that can cover the gap identified in the literature in such a way that is understandable by both practitioners and academics.

3. Methodology

3.1. Research method

In order to create a process reference model a robust methodology is required. The methodological approach followed in this work is an extended version of the methodology described by Gayialis et al. (2013). The authors had followed a Top-Down Bottom-Up approach which was considered fitting in this work as it has been used in the construction process management literature before. Bouchlaghem et al. (2004) used a Top-Down Bottom-Up approach to define the structure of product and information process flows during the design and construction phases of a project. More recently, Pan and Goodier (2012) used a Top-Down Bottom-Up approach to document important issues concerning business models, construction processes and their relationship to offsite construction. **Figure 5** depicts the six methodological steps followed in this research and their position in the Top-Down Bottom-Up approach. Steps one through four were followed by Gayialis et al. (2013); steps five and six are the extension to their methodology added in this work.

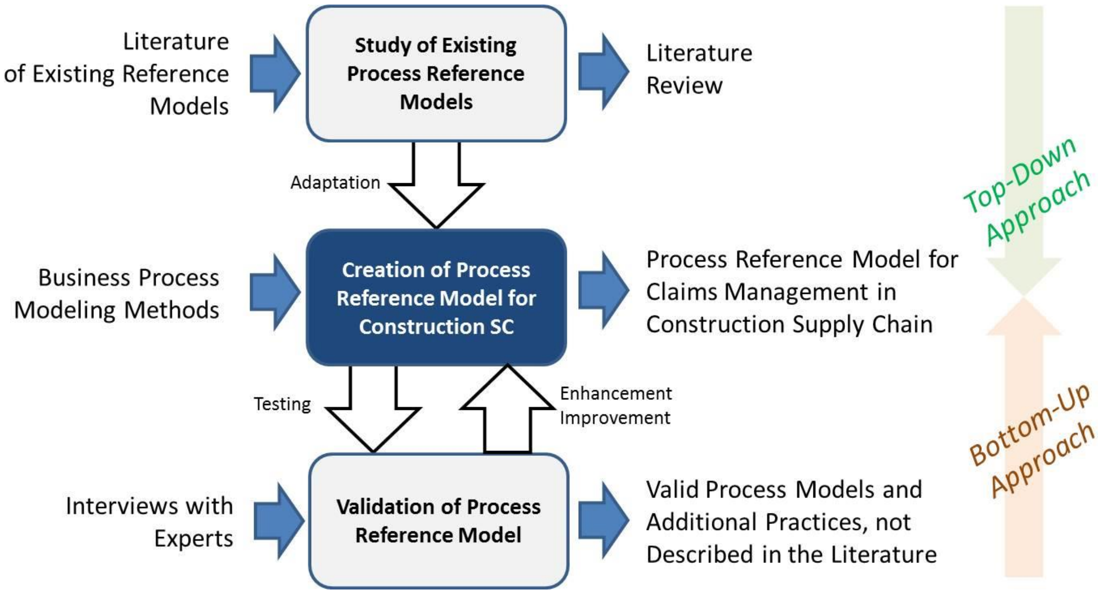

Figure 5: Methodological approach

Step 1: Study of construction supply chain management literature

In this step a review of contemporary theories and practices for construction supply chain management was conducted. Construction particularities, construction supply chain management theory, construction supply chain management problems, and existing supply chain reference models, construction supply chain reference models and processes documented in the literature were analysed. Documented practices, best practices and IT trends in the industry where studied. This step resulted in the identification of basic directions and requirements for the reference model. The outcome of this step is presented in a general literature review seen in the chapter titled "Literature review" and in focused literature reviews for each function of the reference model seen in sections 4.2 through 4.10 under the sub-title "Analysis of…".

Step 2: Study of (construction) supply chain reference models

In this step the top-down approach is applied through the study of other supply chain process reference models (construction and generic). The results of this study can be seen in the section titled “Process reference modelling”. The adaptation and customisation of existing reference models offered the starting point for the development of the reference model presented in chapter “Construction supply chain reference model”. As this research is tied to the research program “ODYSSEUS: A Holistic Approach for Managing Variability in Contemporary Global Supply Chain Networks” and the resulting REMEDY framework (Ponis et al. 2013; Gayialis et al. 2013), the structure of the REMEDY model was maintained. The basic characteristics of the REMEDY model can be seen in the section titled “REMEDY reference model”.

Step 3: Review of methods and tools for business process modelling

The elaboration of the generic REMEDY reference model is based on a set of business process modelling methods and tools which were selected after an extensive literature review and market research. The business process modelling architecture used was based on a set of criteria, including:

- Representation and integration of the different supply chain views, like organisation view, information view, decisional view and risk view.
- Application in different types of business processes: public, private and collaborative business processes.
- Development of reusable models in the form of a reference model.
- Ease of use and understanding by users.
- Existence of a software tool that supports the use of various methods in an integrated way.

The generic REMEDY reference model used an integrated modelling architecture, named ARIS (Scheer and Nüttgens 2000). In this work, a different modelling architecture was preferred, named ADONIS (BOC-Group 2016). The selection process is thoroughly described in the section titled “Process modelling tool selection”. The main characteristics of the generic model were maintained. There are two main reasons behind this transition. First, Kovács (2016) found that the use of process description languages in the handling of construction processes is scattered. Second, recent publications in the general reference modelling literature, such as Verdouw et al. (2011) , and the construction industry process management, such as Teixeira and Borsato (2015) and Cheng, Law, Bjornsson, Jones and R. D. Sriram (2010), have used the BPMN framework. No use of the ARIS framework was identified.

Step 4: Creation of the construction industry supply chain partial reference model

The creation of the construction supply chain partial reference model is based on the outcomes of the previously described methodological steps. The process perspective is graphically represented through the use of value chains, functions, processes, and (when required) sub-processes.

Step 5: Validation of construction supply chain business processes

After the Top-Down approach has been completed through the previous steps, the bottom-up approach for the validation of the results is initiated. For this step, semi-structured interviews were conducted with experienced industry professionals. After assessing the available validation methods (including simulation and case studies), the use of interviews was deemed most fitting for the purpose of this dissertation (in consultation with the supervising professor) as they allowed information collection from multiple sources and, thus, contributed to the generalisability and high level of abstraction of the resulting reference model. Initially, following the methodology for semi-structured interviews described in the book “Research methods for business students” (Saunders, Lewis and Thornhill 2016), five questionnaires were created (Appendix I – Interview Questionnaires) in the following themes: Determine supply chain strategies and performance measurement, Client and supplier relationship management, Demand management and new project development, Work package and construction flow management, and Claims management. The interviews aimed at highly experienced and high level personnel of both SME and large contractors. Due to the high specialisation of construction tasks, the claims management questionnaire had to be aimed at different staff than the rest of the questionnaires. In addition, after the interviews were conducted, it was deemed necessary (again due to the high specialisation of construction tasks) to perform an additional interview regarding the performance management section with a highly experienced business process consultant. **Table 3** depicts the list of interviews conducted and the interviewee profiles. Companies and personal data have been recorded but are not listed in this work for privacy reasons.

Step 6: Identification of best practices not identified in the literature – Identification of differences between different sized companies in the industry

Upon completion of the verification step, in this step the experience and knowledge collected through the interviews was used in two ways. First, the best practices that were not previously recorded in the literature were added to the process reference model. Second, a comparison between the interview results collected from SME contractors and large contractors was conducted in an attempt to shed some light on the differences in their supply chain practices.

This methodology is considered fitting for the aims of this research. Construction projects can be seen as temporary organisations between and within organisations, and therefore standardisation at the multi-project level is difficult as project teams and product designs change from project to project (Hofman, Voordijk and Halman 2009). Standardisation can be achieved through common processes among project participants. In addition, the focus of the reference model on the axis of a portfolio of projects instead of a single project turns attention to the fact that a contractor can consider the flow of projects in a portfolio in much the same way as one considers the flow of products in a production line (Sacks 2016). The reference model developed contains nine functions divided into management processes, core processes and support processes according to Porter (1985). Different levels of process maps include generic maps which focus on activities/practitioners and detailed maps which focus on information and its flow between activities/practitioners, as proposed by Winch and Carr (2001). The generic approach of the constructed reference model aims to provide an overview of the entire supply chain management process, describing its main stages and activities as in the work of Kagioglou and Aouad (1998). Such a tool can be seen as a complementary step to process management improvement in construction companies. As Leblanc et al. (2013) point out: “*process management improvement begins with the development of a generic map focusing on an organisation’s activities and practitioners prior to a focus on the information flow surrounding this through a detailed map*”. The resulting process reference model focuses on the modelling of activities in the project and their relationships using graphical diagrams. This results in intuitive graphical modelling which is mostly concerned with capturing and understanding processes (Aguilar-Savén 2004, Recker et al. 2009).

Table 3: List of interviews and interviewee profiles

	Interviewees					
Theme	Head of SME contractor with over 250 projects (public and private) successfully completed in Greece	Head of SME contractor with over 100 projects (private) successfully completed in Greece	Project manager in large Greek contractor with experience in international projects	Ex project manager in large Greek contractor with experience in international projects/ Currently claims consultant in large claims consultancy in the UK	Chief technical officer of infrastructure projects in large Greek contractor with international experience	Business process management consultant in BOC chapter of Poland with international experience
Determine supply chain strategies and performance measurement	X	X			X	
Client and supplier relationship management	X	X			X	
Demand management and new project development	X	X			X	
Work package and construction flow management	X	X		X	X	
Claims management			X	X		
KPI framework development						X

3.2. Process reference modelling

“A reference model depicts structures, attributes, relationships, and behaviours of objects for a given domain. It is represented in a general, reusable, and applicable form, so that specific application models can be created by adaptation and modification. It serves as a recommendation and framework for future modelling and design tasks.” (Klingebiel 2008)

Reference models are built for specific applications. A reference model should not be considered a ready-to-implement model but a solid starting point for adoption of collective knowledge that has been obtained through studying similar requirements in other organisations (Svensson and Hvolby 2012). Reference models should be set up as configurable models that enable rapid instantiation of specific configurations (Verdouw et al. 2010). Fettke et al. (2005) made extensive research on available process reference models and categorised them according to their characteristics. Supply chain management literature numbers a few process reference models that vary in their characteristics (Figure 6). After extensive research in the supply chain management literature a number of results was listed and analysed based on these characteristics. In most cases, the reference models developed in the industry are copyrighted by consulting companies and there are restrictions to their use, as noted by (Simon et al. 2015).

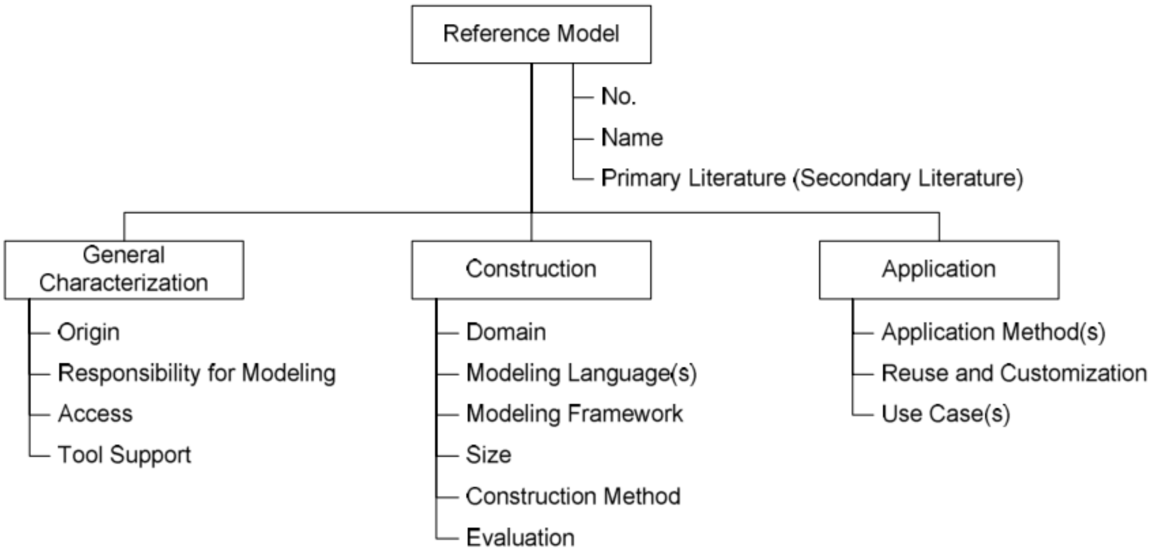

Figure 6: Criteria for describing process reference models (Fettke et al. 2005, p. 470)

Table 4 provides a description of the reference models found in the literature using the method described by Fettke et al. (2005). This method is selected since it is the only available in the current literature. This is not a thorough representation of the reference modelling literature as such a task is not the focus of this work; models were selected based on their citations by other authors.

Table 4: Process reference models in supply chain management

	No	1	2	3	4	5	6	7
Reference model	Name	Supply Chain Operations Reference (SCOR) model	Global Supply Chain Framework (GSCF)	SAP R/3	Collaborative, Planning, Forecasting and Replenishment (CPFR)	Mentzer model	Verdouw model	Klingebiel model
	Literature	(The Supply Chain Council 2010)	(Croxton et al. 2001)	(Keller and Teufel 1998)	(Seifert 2003)	(Mentzer et al. 2001)	(Verdouw et al. 2011)	(Klingebiel 2008)
General Characterization	Origin	Practice	Practice	Practice	Practice	Science	Science	Science
	Responsibility for Modelling	Supply Chain Council Inc.	Global Supply Chain Forum	SAP AG	Voluntary Inter-Industry Commerce Standards Association (VICS)	Authors	Authors	Authors
	Access	Limited	Limited	Limited	Limited	Open	Open	Open
	Tool Support	Yes	No	Yes	No	No	No	No
Construction	Domain	Function	Function	Other	Function	Function	Function	Function
	Modelling Languages	Graphical and Verbal	Graphical and Verbal	EPC, ERM, Function Tree	Verbal	Verbal	Verbal	Verbal
	Modelling Framework	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Size	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Construction Method	N/A	Literature review and interviews with leading market players	N/A	N/A	Analysis of literature / conceptual	Analysis of existing SCOR reference model	Empirical
	Evaluation	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Appli-cation	Application Methods	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Reuse and Customisation	Specialisation	Specialisation	Specialisation	Specialisation	N/A	N/A	Very low
	Use Cases	Multiple	Multiple	N/A	Multiple	N/A	N/A	N/A

In construction a reference model is considered “*a general, project-independent description of the flow of a building project's design process that adheres to today's accepted practice, its tasks and many dependencies*” (Lahdenperä and Tanhuanpää 2000). Analysis of the construction management literature provides poor results for process reference models in the field of construction supply chains. The most notable results are: “The generic design and construction process protocol” developed by Kagioglou et al. (Kagioglou et al. 2000; Aouad et al. 1998; Cooper et al. 1996), the adaptation of the GSCF model by London and Kenley (2000), and the adaptation of the SCOR model by Thunberg and Persson (Thunberg and Persson 2013, Thunberg 2013, Thunberg and Persson 2014). The first result is a process reference model focused on IT development in design and construction phases of construction projects, the second result is an effort to adapt the process-based GSCF model to the needs of the construction industry, and the third describes the adaptation of SCOR and its metrics to the construction industry particularities. Each of these models faces certain constraints. The only model that has been updated is the third one. Its main problem though is that it does not describe any processes. There are other modelling attempts in the construction industry that do not focus on the supply chain of a project and are not mentioned in this section as they are not considered part of this dissertation.

SCOR is the leading reference model across industries. It is highly popular, especially in the manufacturing industry. It is an operational reference model that connects defining and describing processes with tetechnology, best practices and measurement (Wondergem 2001). SCOR allows organisations to: evaluate processes effectively, compare performance in selected discrete operational areas, pursue specific competitive advantages, identify and carry out supply chain improvements, promote and manage internal change, use recorded industry best practices and benchmark their performance, quantify benefits related to changes, identify suitable software according to process requirements, provide a training framework for supply chain management, improve business agility and carry out many other other tasks (The Supply Chain Council 2010, APICS 2018). The reference model is comprised of four levels of analysis (top level, configuration level, process element level, implementation level), of which the three higher levels are described by the reference model whereas the fourth level is company specific and out of the model’s scope. Processes are grouped in six functions, namely Plan, Source, and Enable. Plan holds a higher level than all the other functions and directly affects the Source, Make, Deliver and Return functions. Enable holds a lower level than all other functions and supports the application of Source, Make, Deliver and Return functions. Typical performance measures include reliability, responsiveness, agility, costs and asset management specificity. Despite the wide acceptance of SCOR, it is not deemed to provide the appropriate basis for this dissertation due to the following reasons:

- There are no detailed descriptions of processes available to provide a basis for the construction reference model creation
- Access to detailed information is restricted to subscribers
- The high level description available for the functions does not adequatelly fit the profile of the construction industry and its characteristics
- The strength of the reference model lies with the repetitive execution of specific supply chain processes for specific products. It is hard to apply this to construction projects as each project is unique.

- Improvements resulting from the use of the reference model can be applied faster when processes are repeated with specific clients that provide feedback. In construction it is very hard to have repeat business with clients and construction clients hardly provide any feedback regarding improvement of supply chain processes.
- There are no supply chain best practices recorded in the construction supply chain management literature that can provide a background for benchmarking, a critical parameter of SCOR.
- The adoption of SCOR requires a certain level of process maturity. Mature processes are hard to develop and the fact that the construction industry is vastly dominated by SMEs that lack the funds, know-how and willingness to assess their process maturity makes it hard to adopt SCOR.

A reference model that describes a specific set of functions and processes is required to provide a starting point for the development of the construction supply chain process reference model. In addition, the generic reference model should provide a function related to new product development as this is a critical function in construction supply chains due to the uniqueness of each new project. The supply chain REMEDY process reference model, which is described in section 3.3, covers these two basic research requirements and is thus selected in this dissertation to provide the basis for the adaptation and creation of the construction supply chain process reference model.

3.3. REMEDY reference model

The SC REMEDY model was developed through the research program “ODYSSEUS: A Holistic Approach for Managing Variability in Contemporary Global Supply Chain Networks”. The research team included both academic staff and PhD students (including the author of this dissertation) from four universities across Greece. Each university was assigned specific tasks of the project. The National Technical University of Athens developed the initial reference model and that provided the function and process views used to link the risk, decision and information views developed by the University of the Aegean, University of Thessaly and Athens University of Economics and Business respectively. Besides the project deliverables available online (http://odysseus.simor.ntua.gr) the research has been diffused through numerous publications in the literature (http://odysseus.simor.ntua.gr/project-results/publications.html). It draws on the basic structures of the GSCF model (Croxton et al. 2001) such as process decomposition, discrimination of strategic and operational functions, and the analysis of functions into long-term and short-term processes. GSCF processes were enriched by knowledge derived from a set of business process analysis case studies in supply chains of various sectors (energy, wood and furniture, metal forming, consumer goods, food and beverages, apparel, pharmaceuticals and cosmetics). This was realised through a top-down bottom-up methodology described extensively by Gayialis et al. (2013). Processes in the SC REMEDY model were connected to a framework of supply chain performance measurement metrics based on the SCOR (The Supply Chain Council 2010) tool. The model attempts to identify and evaluate the consequences of poor demand variability management. To do so it employs a multitude of views, namely function view, organisation view, information view, decisional view, risk view and knowledge view. Processes play a central role in the model as they connect all other views. The ‘‘ARIS Platform’’ software tool was utilised to support the integration of the aforementioned views. Processes extend over three tiers (supplier, organisation, and client) of a supply chain. This is done through nine major core business functions, namely ‘Determine supply chain management strategies’, ‘Customer relationship management’, ‘Product development and commercialisation’, ‘Supplier relationship management’, ‘Develop framework of metrics’, ‘Demand management’, ‘Order fulfilment’, ‘Manufacturing flow management’, and ‘Returns management’. All functions are decomposed through function trees in a set of strategic and operational processes. The strategic level relates to the definition of long-term activities implementation and the operational level concerns their short-term implementation. Each process is analysed through Event-driven Process Chain (eEPC) diagrams that integrate function, organisational, information, knowledge and risk views. A total of one value chain, nine function trees, ninety-two extended Event-Driven Process Chains, fourteen risk trees, nine decision trees, three organisational charts, and one application system diagram comprise the modelling effort. Knowledge views were associated with the most important decisions in the model. Furthermore, the model was complemented with a risk breakdown software system and mathematical modelling tools to support the decisional view. Risks included cover the operational, environmental and financial aspects of a supply chain. Quantitative models and algorithms used in decision support are provided to support accurate demand forecasting and efficient inventory replenishment. The SC REMEDY model focusses on demand variability management in a variety of industries through its generic nature. Partial reference models have been developed focusing on the particularities of the Make-to-Stock, Make-to-Order, Hybrid, and Energy industries.

3.4. Process modelling tool selection

The process modelling literature is abundant with techniques that have been developed in the industry, in academia, or in institutions. It is difficult to pick out a certain technique as the best, as different techniques excel at different aspects. Thus, it is critical to decide upon a set of criteria that these techniques will be benchmarked against in order to make an informed decision. The criteria selected must cover all aspects of a modelling technique but cannot be of equal weight. The criteria selected in this work are the following: completeness of modelling views, existence of modelling tool, ease of comprehension, reusability, depiction of both intra- and inter-organisational and cooperative processes, and reference modelling capabilities. The criterion with the heaviest weight in this this work is the existence of a modelling tool. Based on this criterion, many modelling techniques were not entered in the final evaluation stage. First, it is deemed necessary to clarify the meaning of business modelling concepts. The relationships between the concepts of architecture, modelling framework, methodology, model, modelling dimension, modelling tool, and modelling method are depicted in **Figure 7**.

- Architecture: A modelling architecture depicts a sum of structured knowledge that can be used to configure processes and embed them in the organisational structure.
- Modelling framework: A modelling framework provides the overall picture of possible organisational aspects that can be modelled.
- Methodology: Methodology includes the modelling languages and techniques used to depict modelling objects.
- Model: A business model describes core aspects of organisational value creation, delivery and capturing.
- Modelling dimensions: A modelling dimension is a view included in the selected modelling framework.

- Modelling tool: A modelling tool is the software solution that applies the modelling methods.
- Modelling method: A modelling method is used to depict a business model. Examples of such methods are flowcharts, business process modelling notation (BPMN) and extended event-driven process chain (eEPC).

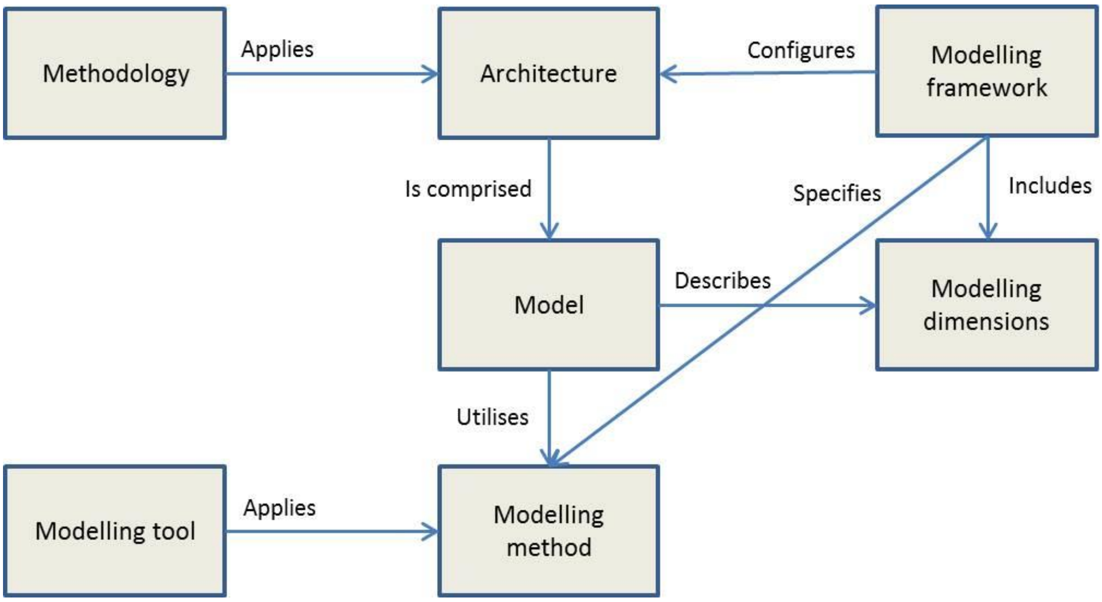

Figure 7: Business modelling concept relationships (adapted from Gayialis 2011, pg.8)

A brief description of available modelling architectures follows:

- Zachman framework: Developed by Zachman in 1987, it is the first documented enterprise architecture. The generic classification structure of design artifacts is a six by six bounded matrix (**Figure 8**) who's each cell provides information on certain iterations.

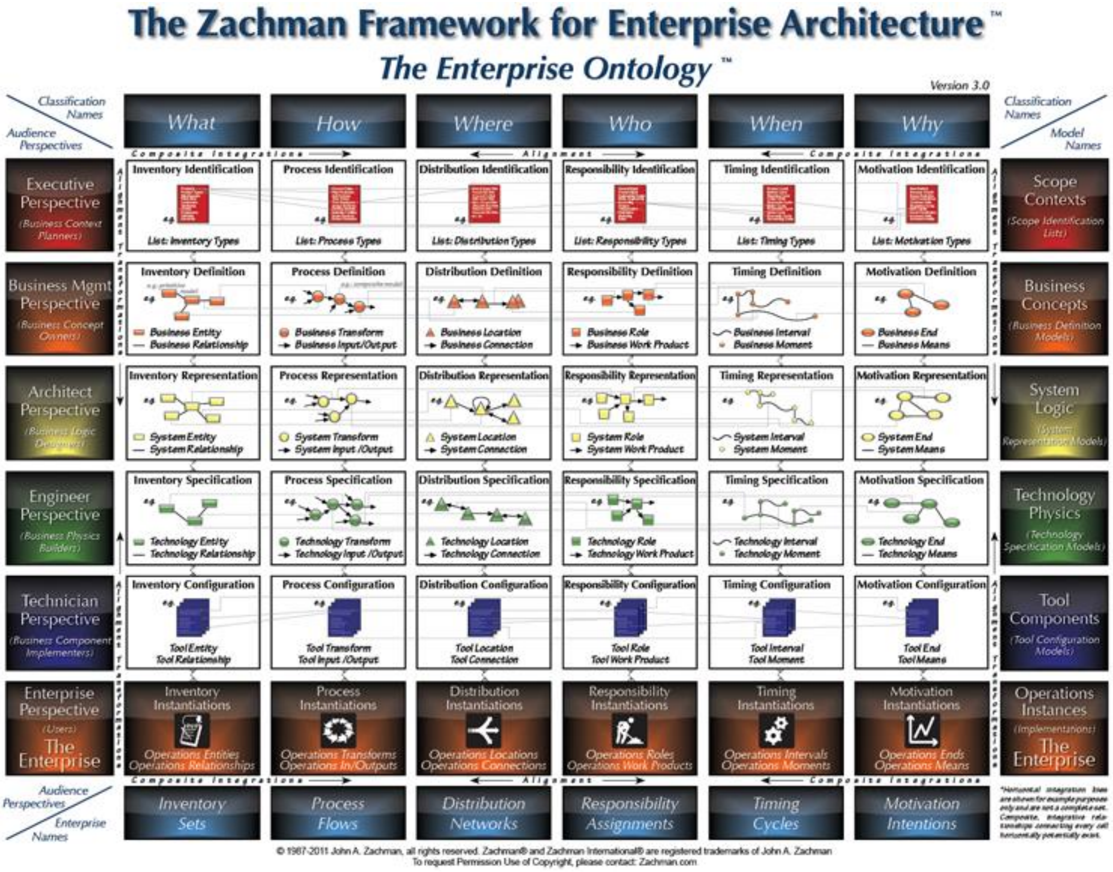

Figure 8: Zachman framework for enterprise architecture (Zachman 2008)

- Architecture of Integrated Information Systems (ARIS): Developed by academic Dr. A. Scheer from the University of Saarland in 1992, it is now offered by Software AG. It describes enterprise architecture through five views (control, organisation, data, function, product/service) that comprise the “ARIS House” supported by a large number of modeling techniques that cover almost every aspect of enterprise architecture (Scheer and Nüttgens 2000).
- ADONIS BPMS framework: Initially developed in the University of Vienna, it is now offered by the BOC consulting group. The framework offers five scenarios (business process management, risk management, process implementation, compliance management, initiative and change management) supported by interrelated modeling techniques (BOC-Group 2016).
- Enterprise Architecture Planning: Developed by Steven Spewak in 1992. It is comprised of seven phases [planning initiation (1), business modelling (2), current systems and technology (2), data architecture (3), applications architecture (3), technology architecture (3), implementation/migration plans (4)] that have been placed into four layers (1. Getting started, 2. Where are we today, 3. Future vision, 4. How to get there) (Spewak and Hill 1993).
- Integrated Architecture Framework: Developed by consulting company Capgemini in 1993, this framework is based on the Zachman framework. The framework uses abstract levels (why, what, how, with what) that breakdown problems into smaller parts. These levels are applied to business, information, information systems, and technology infrastructure security and governance.

- Generalised Enterprise Reference Architecture and Methodology (GERAM): Developed in the 1990s, GERAM is a generalised framework that focusses on enterprise integration and business process engineering. It is comprised of eight components (generic enterprise reference architecture, enterprise engineering methodologies, enterprise modelling languages, enterprise modelling tools, enterprise models, generic enterprise modelling concepts, partial enterprise models, enterprise modules, enterprise operation systems) interrelated as seen in **Figure 9**.

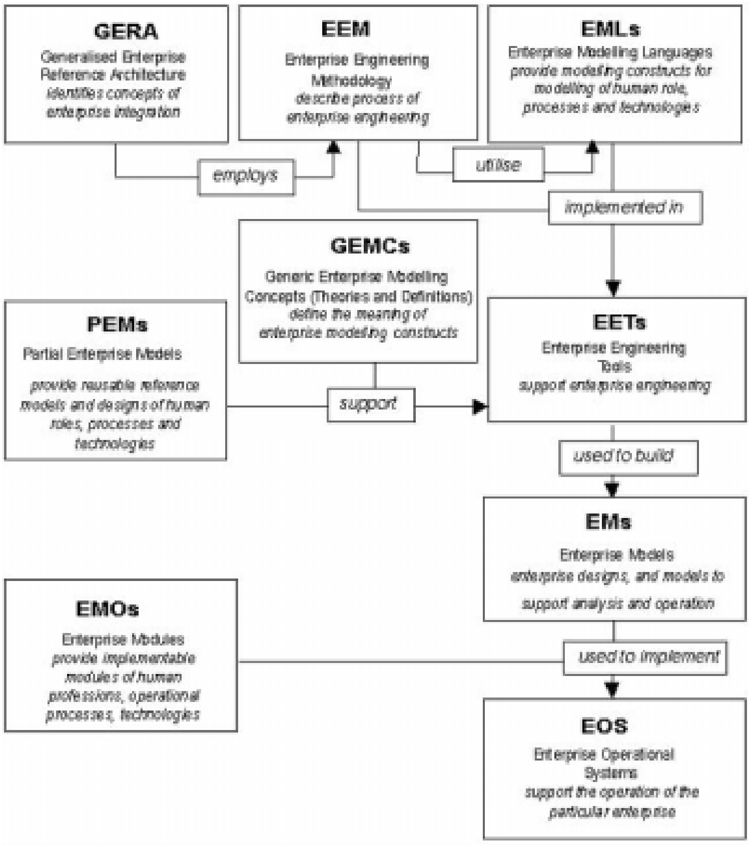

Figure 9: Generalised Enterprise Reference Architecture and Methodology (IFIP-IFAC task force as seen in Baabak et al. (2007), pg. 40)

- Semantic Object Model approach (SOM): Developed in 1997 by Otto Ferstl and Elmar Sinz. It is based on a systems theory background and supports the basic phases of business modelling (analysis, design, re-design) a complex combination of perspectives, model layers and specifications describing three views (enterprise plan, business process model, specifications of organisational charts, application systems and machinery) (Ferstl and Sinz 2006).
- Multi-perspective Enterprise Modelling: Developed in the early 1990s, this architecture is based on the Zachman framework. It is comprised of three views (strategy, organisation, information system) that are described by four dimensions (resources, operations, results/success factors, external system) (Frank 1994). High levels of abstraction are preferred in this architecture.
- The Open Group Architecture Framework (TOGAF): Developed by companies in the 'The Open Group' consortium. There have been nine different versions of the framework and the latest one is comprised by seven sections (introduction, architecture development method, architecture development method guidelines and

techniques, architecture content framework, enterprise continuum and tools, TOGAF reference models, architecture capability framework) (The Open Group 2011).

- Extended Enterprise Architecture: Developed in 2000, this architecture aims to define three compounds of enterprise modelling (construction, operation, and aesthetics). According to Schekkerman (2006) enterprise architecture mirrors culture, values, rules, and principles of each organisation. Four views are used in this framework (business, information, IT, technological infrastructure).
- MIT EA management approach: Developed by academics in Michigan Institute of Technology. It focusses on embedding goals in decision making processes and coordination of decisions across business functions (Leonidis 2016). It defines four levels of maturity for the architecture (business silos, standardised technology, optimised core, business modularity).
- TU Lisbon Management approach: Developed in 2003 by academics in the Technical University of Lisbon. It uses UML modelling language for enterprise modelling (Leonidis 2016).
- Systemic Enterprise Architecture Methodology: Developed in 2002 by Alain Wegmann. It provides an optical approach for system modelling (Wegmann 2002). It uses entity levels to structure the architecture.
- ArchiMate: Developed in 2003 by a company named Telematica. It provides a common language for the description of business processes, operational structures, information flows, IT systems, and technical descriptions. This allows decision makers to see the effects of their decisions on and between these views (Ettema and Dietz 2009). It divides enterprise architecture into business, application and technology environments and focuses on passive structures, active structures and behaviour in each environment.
- KTH Stockholm EA management approach: Developed in 2004 by academics in KTH Stockholm University. The chief information officer plays a key role in this framework by performing strategic decisions related to information systems. A key feature of this framework is the extended influence diagram, a technique that can describe qualitative characteristics (Leonidis 2016).
- Building blocks for Enterprise Architecture Management Solutions: Developed in 2004 by academics in the technical University of Munich. It is based on the principles of communication and architecture phase development in a project portfolio, analysis and evaluation of scenarios (planned states), and development and adaptation of management principles (Buckl et al. 2010). Variables are a key element of this approach.
- Finnish Enterprise Architecture Research: Developed by academics from Jyväskylä University in Finland (Leonidis 2016). As all documentation is in Finnish, there is no more information available.
- Methodology for (re)design and (re)engineering organisations: Developed by academics from Delft University in the Netherlands in 2005. It focusses on rapid re-organisation of enterprises through three views (enterprise, information, documentation) that are hierarchically structured with enterprise view on the top (Leonidis 2016).
- EA^3 Cube^{TM}: Developed in 2004. It focusses on five views of enterprise architecture (strategy, business, information, systems, networks) and aims at designing enterprise architecture and optimising IT resources (EA3 2017).

- Dynamic Architecture for modelling and development: Co-developed in the Netherlands by academics and a corporation in consulting in 2001. It is based on four principles (architecture process is as important as architecture products, ease of change, deviations from the architecture are acceptable, development of architecture is based on “just in time, just enough” principle) (van Steenbergen, van den Berg and Brinkkemper 2007). It is comprised of four key processes (strategic dialogue, development with architecture, development without architecture, architectural services) that interact with both governance and dynamic architecture (Wagter et al. 2005).
- Niemann EA management approach: Developed by industry expert Klaus Niemann in 2005. It describes the enterprise architecture cycle that is comprised of five phases (document, analyse, plan, act, check) (Niemann 2006). This cycle is applied to three levels of detail (business architecture, applications architecture, systems architecture) that are described as a pyramid with business architecture at the top.
- Hanschke Strategic IT management: This framework was developed by Hanschke in 2010 as a set of best practices in enterprise architecture management. It describes methodologies for corporate, technological and information views of enterprise architecture (Hanschke 2010). Its main focus is on the information view where four main processes (documentation, analysis, design, and governance) are considered and the support of IT in their interfaces and interconnections is analysed.
- Computer integrated Manufacturing Open System Architecture (CIMOSA): Developed in 1990 by a consortium of companies (including HP, IBM, FIAT, Siemens, etc.) titled AMICE. CIMOSA focuses on a broad set of organisational activities. It is comprised of three levels of modelling (requirements definition, design specification, implementation description) that cover four views (organisation, resources, information, function) through three levels of abstraction (generic building blocks, partial models, particular models) (ESPRIT Consortium AMICE 1989). Its main function is to support the design and implementation of organisational systems.
- Federal Enterprise Architecture Framework: Developed and published by the US Federal Chief Information Officers (CIO) Council in 1999. It breaks down enterprise architecture in four partial architectures (business, data, applications, technology) (Urbaczewski and Mrdalj 2006). It is mainly used by the US government for department management systems.
- Department of Defence Enterprise architecture: Develop by the US Department of Defence in 2003. It includes three views (operational, system, technical) whose interrelationships can be seen through a master view named “All views” (Urbaczewski and Mrdalj 2006). It focuses on decision support.
- Treasury Enterprise Architecture Framework: Developed by the US Department of Treasury in 2000. It includes four views (functional, information, organisational, infrastructure) across four perspectives (planner, owner, designer, builder) (Urbaczewski and Mrdalj 2006). It was abandoned in 2012.

Most of the frameworks described above have been disqualified from the selection process as they do not meet the basic criterion of being supported by a tool. The architectures that are supported by software tools are evaluated as seen in **Table 5**.

Scheer and Nüttgens (2000) argue that process models should cover the whole enterprise life cycle, analyse the different process views and incorporate reusable models in the form of reference models. As seen in **Table 5**, the most fitting architectures are ARIS and ADONIS. The next step was to identify the most commonly used modelling technique in the construction supply chain literature. Simple flowcharts are the most widespread process flow technique, but they do not allow for accurate depiction of both intra- and inter-organisational and cooperative processes. BPMN was identified as the most commonly used technique in publications (Kovács 2016, Cheng, Law, Bjornsson, Jones and R. Sriram 2010). As Recker et al. (2009) underline, BPMN is the most fitted modelling technique for describing properties and types of things, systems structured around things, and presents a very high degree of completeness for events and transformations occurring on things compared to other process modelling techniques. This technique is offered by both ARIS and ADONIS, thus attention was turned to the tool availability criterion. As it is the intention of this work to provide an accessible reference model to anyone interested, the modelling tool has to be equally accessible. This criterion is only met by ADONIS (community edition), thus this modelling framework and its accompanying tool are used in this work.

Table 5: Evaluation of enterprise architectures

	Criteria					
Architecture	Completeness of modelling views	Ease of comprehension	Reusability	Depiction of both intra- and inter-organisational and cooperative processes	Reference modelling capabilities	Tool availability
ARIS	High	High	High	Partial	Yes	Licence
ADONIS	Medium	High	High	Yes	Yes	Licence/Free
SOM	Low	High	High	-	-	Free
TOGAF	-	High	High	-	-	Free
SEAM	-	High	High	-	-	Free
ArchiMate	-	High	-	-	-	License
Hanschke	-	-	-	-	-	Free

ADONIS CE is a freely accessible business process management tool provided by BOC Information Technologies Consulting GmbH. The tool offers features including process modelling, documenting object attributes, queries and reports, process simulation and process publishing. It allows users to design, document, communicate, analyse, optimise, implement, measure performance and improve processes while managing the risks associated with tasks at various levels of detail. It can support process lifecycle management and assist in increasing quality and customer satisfaction, while reducing cycle times and costs. The main benefit offered by the use of this tool is that the reference model developed can be diffused to interested users without requiring a prior software investment.

4. Construction supply chain reference model

4.1. Introduction

The REMEDY process reference model was selected as the basis for the development of the construction supply chain reference model. The REMEDY model can be applied to any tier of the manufacturing supply chain with very few adjustments. The construction supply chain particularities though dictated that a specific tier of the supply chain should be focused upon. The contractor[3] was selected as the models' focal company since contractors have the technical or management know-how to carry out the project for the client. This is in line with the description for contractors provided by Ronchi (2006): "*The principal agent thus is the general contractor that selects, organizes, coordinates, and manages subcontractors and specialists along the construction supply chain*". Furthermore, contractors are tightly related to a project's success (Alzahrani and Emsley 2013) and clients do not tend to participate in project procurement practices (London, Kenley and Agapiou 1998, Cox, Ireland and Townsend 2006B). Downstream, the client, consultants and designer are all considered as the "Client" in the model as such organisations are implicated in the project upon client's request and represent the client's interests. Upstream, all material, service, and specialist subcontractors are considered as the "Supplier" as these organisations are implicated in the project in order to supply contractors with whatever they are requested to. The majority of upstream contractor relationships are made up of financial, technical, contractual and inter-personal entities that only extend a single tier in the supply chain (Pala et al. 2013). According to the approach followed in the development of the REMEDY model, the model presented in this chapter is considered a partial reference model as it focuses on a specific industry. The original structure of the REMEDY model was manufacturing-centred and, thus, a large extent of changes was required for the construction industry. **Table 6** and **Table 7** depict some of the differences between the two models and the extent of modifications required for the development of the construction supply chain model.

Table 6: Differences between generic and partial reference model

Generic supply chain reference model		Construction supply chain reference model	
Functions	Number of processes	Functions	Number of processes
Determine supply chain management strategies	8	Determine supply chain management strategies	3
Customer relationship management	16	Client relationship management	14
Product development and commercialisation	12	Project development and commercialisation	9
Supplier relationship management	10	Supplier relationship management	11
Develop framework of metrics	8	Develop key performance indicator framework	2
Demand management	9	Demand management	9
Order fulfilment	10	Work package management	8
Manufacturing flow management	7	Construction flow management	7
Returns management	10	Claims management	5

[3]Contractor is used to describe the organisation that has been assigned with the responsibility to carry out, manage, and deliver the finalised project to client.

Table 7: Extent of modifications to the generic REMEDY model processes

Function	# of generic model processes maintained	# of deleted processes	# of new processes	# of adapted processes	Sum of processes
Determine supply chain management strategies	0	8	3	0	3
Client relationship management	3	2	2	9	14
Project development and commercialisation	2	0	0	7	9
Supplier relationship management	1	1	3	8	11
Develop key performance indicator framework	0	8	2	0	2
Demand management	1	0	0	7	9
Work package management	0	10	8	0	8
Construction flow management	0	3	3	4	7
Claims management	0	10	5	0	5

In further analysis, “Customer relationship management” was renamed to “Client relationship management” for reasons explained in the respective section (pg. 87), “Product development and commercialisation” was renamed “Project development and commercialisation” as the construction product is the concluded project, “Order fulfilment” was replaced by “Work package management” as work packages constitute the client’s order for a specific aspect of the project, “Manufacturing flow management” was replaced by “Construction flow management” that manages day to day work site logistics and operations, and finally, as there are no returns by the client to the contractor “Returns management” was replaced by “Claims management”. The number of processes has therefore been adjusted as processes belonging to a function of the general model were either replaced by more fitting ones in the partial model or deleted entirely if they had no applicability to the construction industry. Furthermore, a large number of processes were maintained, but their tasks were either moderately or extensively adapted to the particularities of the construction industry. The value chain of the construction process reference model is comprised of four management, four core and one support functions, as seen in **Figure 10**. The focus of the model is on integration of processes and flows between parties, as the general supply chain management literature proposes (Bankvall et al. 2010). The model attempts to cover and unify concepts that have diachronically been highlighted in the literature such as supply chain relationships in the context of different business trends (vertical disintegration, supplier-base reduction, focusing of operations, outsourcing, just-in-time, partnerships and partnership sourcing) (Harland 1996), functional areas that are linked closely together under construction supply chain management (purchasing, logistics, materials management, construction) (Benton and McHenry 2010), and the design, construction and handing-over stages of building construction projects (Olander and Landin 2005) in order to provide sufficient control over project outcomes (Bildsten and Manley 2015). In the rest of this chapter the literature background for each function is analysed and each function is presented including the findings from the interviews conducted.

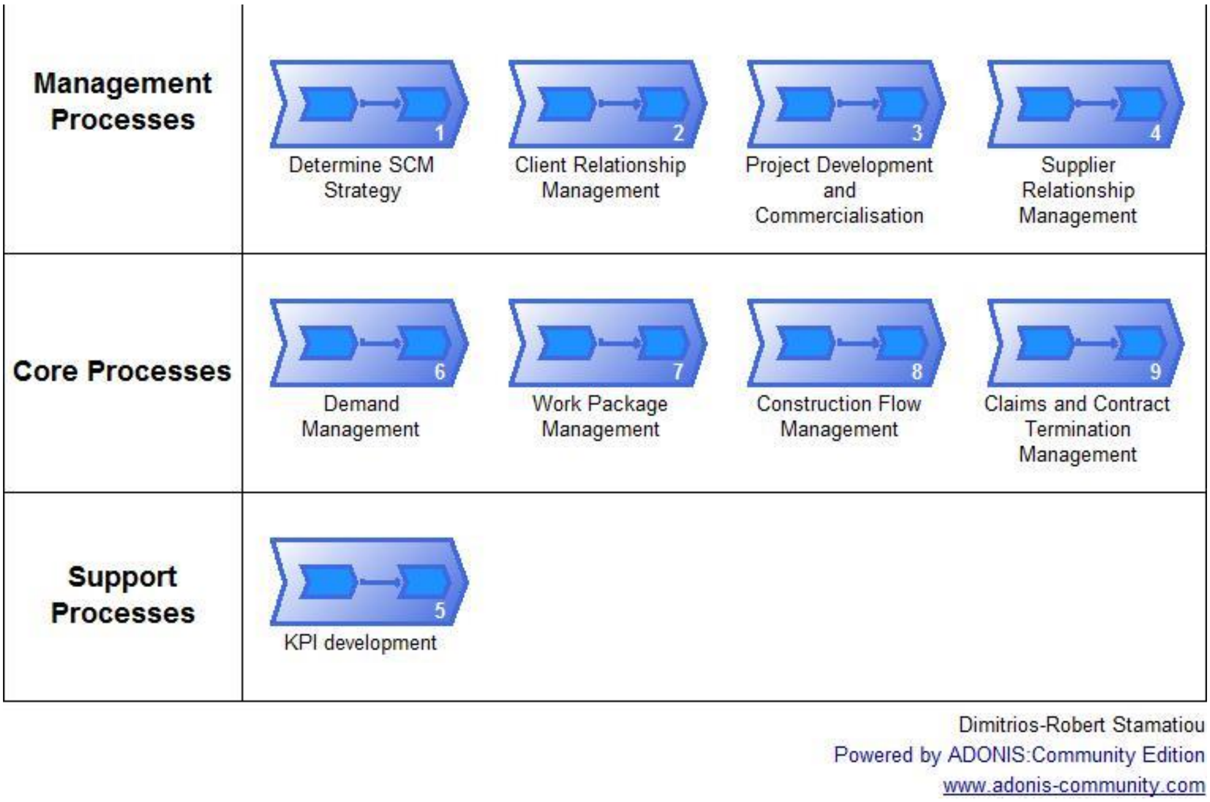

Figure 10: Construction process reference model value chain

4.2. Determine supply chain management strategies

4.2.1. Analysis of supply chain management strategies

In order for construction companies to survive, they have to undertake and complete projects according to their clients' requirements. Different types of projects require different skillsets, and the fact that a contractor decides to bid doesn't mean that he will be assigned with the execution of the project. Clients can choose contractors from a pool of available offers based on their criteria. This means that contractors have to formulate a specific strategy in order to ensure their survival. Proper management of a project can make it profitable, satisfy the client, maintain good reputation, and generate repeat contracts in an environment of increasing competition (Parfitt and Sanvido 1993). Each contractor should have a vision that describes the future it wants to create and a strategy that will implement the vision (Romano, Grimaldi and Colasuonno 2016). An integral part of the whole strategy is the supply chain strategy the contractor selects to follow. A supply chain management strategy that supports the general business strategy can lead to better performance and a competitive advantage (Qrunfleh 2010). Collaboration is imperative and the questions around it have to relate as to how it will be conducted (Poirier, Forgues and Staub-French 2016). After contracts have been signed, the contractor has to select how resources, internal or external, will be mobilised in order to fulfil the obligations undertaken (Winch 2001). The challenge for each and every contractor is to identify the appropriate strategy for each project's supply chain and then manage the supply chains of all the projects simultaneously (Christopher, Peck and Towill 2006). The higher the level of supply chain practices, the higher the level of supply chain performance (Sukati et al. 2012). Day (1990) (as seen in Lambert (2010)) proposes that strategies guide actions and decisions in terms of: "*the markets to serve and customer segments to target; the positioning theme that differentiates the business from its competitors; the channels used to reach the market; and the appropriate scale and scope of activities to be performed*". Supply chain strategy, in particular, involves identification of critical supply chain members, interaction processes, and type/level of integration for each process (Croxton et al. 2001). Construction supply chains are different for each project and can be described as a "*system of multiple supply chains delivering all raw materials, human resources and information required for the successful completion of a project to the place where the specific end product must arise*" (Cox, Ireland and Townsend 2006A). In construction, firms, projects, markets and commodities are associated dynamically and complexly, thus challenging contractors to manage their supply chains (Hughes et al. 2006). Lack of knowledge about contractor's partner behaviours makes coordination in construction supply chains a very complicated task (Grandori 1997). Additionally, lack of knowledge of supply chain management practices by contractors make governing the construction supply chain very hard. Counter to the norm of fragmented ad hoc application of supply chain management initiatives, a holistic approach to supply chain management is needed by contractors (Love, Irani and Edwards 2004). Such approaches can lead to improved supply chain performance (Sukati et al. 2012). Holistic approaches entail management of supply chain partners (suppliers and clients) at both a strategic and operational level, management of current and future demand levels, and management of day to day planning and execution activities at the construction site. This demands the outlining of strategies that will govern all those aspects in a uniform but flexible way.

A basic prerequisite for successful projects is that relationships between partners are kept at an acceptable level. Traditionally, relationships between construction project parties are managed through procurement, purchasing, and contract management (Khalfan et al. 2001). These practises, although deeply rooted in the industry, cause problems in managing supply chains and process integration (Briscoe and Dainty 2005). Supply chain strategies must be carefully formulated, strategically planned, organised and executed (Aloini et al. 2012B). According to Palaneeswaran et al. (2003), contractors and subcontractors have to consider managerial, organisational, relational and technological issues when creating models and techniques for their supply chain strategy. Contractors have to keep in mind that, despite the use of some subcontractors across multiple projects, each project has a unique supply network (Briscoe, Dainty and Millett 2001) while coordination of resources has to occur at the project level, firm level and relationship level across many projects simultaneously (Håkansson and Jahre 2004). As Love et al. (2004) underline, "*SCM recognizes interdependency in the supply chain and seeks to improve its configuration and control base by integrating inter and intra organizational business processes*". There are three types of supply chains relevant to contractors: temporary supply chains, framework-specific supply chains and company strategic supply chains (Dubois and Gadde 2000). These supply chains are subjected to limitations caused by serial, reciprocal and pooled task or product interdependencies that coexist (Håkansson and Jahre 2004). These interdependencies not only affect project tasks, but also the contracts signed with the relevant parties. Additional costs are added to contracts due to uncertainties regarding the work offered (Isatto and Formoso 2011). These uncertainties are carried from the client upstream the supply chain when they are mitigated through the contracts. One way the contractor can reduce these uncertainties is through the establishment of a strategic position (Dikmen and Birgönül 2003). According to Porter (1985), there are three distinct generic competitive strategies from which to choose: differentiation, cost-leadership and focus. Dikmen and Birgönül (2003) support that, when attempting to follow the differentiation strategy, the main concern is to offer a unique product in the industry that is valued by clients, without overlooking cost issues. In order to adopt cost-leadership in the construction industry, a contractor has to improve competitiveness by being the lowest responsive tenderer, lowering production costs or aiming at attaining minimum costs for construction activities, whereas focus strategy would require construction companies to use their strengths in core competencies to add value to the entire construction process (Price and Newson 2003). Tan et al. (2012) found that contractors in Hong Kong that implemented one of these strategies gained superior performance when the business climate was favourable. Examining the characteristics of each strategy, differentiation can be followed by resolving time-related issues, improving project delivery and keeping the same level of quality (Kale and Arditi 2003). Cost-leadership strategy requires low-cost and innovative attributes in the formation of the strategy, without lowering quality standards, whereas focus strategy requires the adoption of cost advantage attributes (Oyewobi, Windapo and James 2015). In order to select one of the aforementioned strategies, it is important to define what construction strategy is in order to reach a consensus both internally and externally to a project. Tran et al. (2012) performed an extensive literature review on construction strategies and came up with the following definition:

"A strategy mode, consisting of a combination of one or more system, subproject and project level strategies, shaped by client objectives, project constraints and conditions, for a spatial/system element as of a specific point in time."

Contractors are the firm with the largest influence on a project and the related supply chain and can exercise different levels of control over each supply chain party (Pala et al. 2013). This could either be related to the size of the contractor firm or to the client that secedes power to the contractor in order to manage the project supply chain (Jones and Saad 2003), depending on the type of contract (Smyth 2005). As mentioned in the Literature review, despite their dominant position in the supply chain, contractors focus on the demand side of the chain while at the same time they fail to examine supplier needs. Cheng et al. (2001) identified the trend of project whole-life-cycle developing in practice that requires contractors to focus on both sides of the supply chain. Integration of suppliers, the grail of construction supply chain management literature, requires that relationships are managed in all of their aspects. Eriksson (2015) proposes four dimension of integration: strength, scope, duration, and depth of integration.

Contracts between the client and the contractor are the result of a bidding process, thus, the first step to managing the supply chain is to acquire the clients' contract. This makes the decision to bid the most important decision in construction projects. Soo and Lan Oo (2014) studied the literature and found the following factors that affect the decision to bid: need for work, client identity, degree of hazard, number of competitors tendering, experience in such projects, type of job, current workload, and historic profit. Likewise, they found the following factors that affected the price tag: degree of difficulty, risk, current workload, type of job, need for work, estimate uncertainty, contract conditions, and historic profit. Public projects in particular have a large amount of administrative requirements and are less flexible to approach (Ning and Ling 2013) making the decision to bid all the more complex. Another important decision is the type of relationship that will govern interactions between parties. According to Håkansson and Snehota (1995), there are four variables that can be used to describe relationships in the supply chain: continuity, complexity, symmetry and informality. Based on these variables, there are four relationship types: transactional, series of transaction, project collaboration and Long-Term Strategic Partnering relationships (Pala et al. 2012). The first type of relationships, transactional relationships, are the most common type of relationship in construction supply chains and they are based on short, simple, once-off and price-based transactions (Thompson, Cox and Anderson 1998). Series of transaction relationships describe more intense and frequent transactions between parties that are still based on price (Cox, Ireland and Townsend 2006B). Project collaboration are close relational agreements that occur for a single project and either depict the evolution of series of transactions relationships over time or are based on a strategic decision for closer collaboration (Gadde and Dubois 2010). Finally, Long-term Strategic Partnerships relationships are based on long-term high-level strategic decision between partners (Gadde and Dubois 2010). Each relationship type requires the appropriate type of tools, processes, procedures and motives in order to maintain the agility, efficiency and smoothness of the interaction (Pala et al. 2013). This means that strategic decisions can have different levels of impact on each relationship (Ford and McDowell 1999). Cox et al. (2006a) support that while there are opportunities to move towards more long-term relationships, these will mainly remain in a short-term and relatively opportunistic nature. This indicates that there is need to support these transitions towards more collaborative working with special tools and adoption of other management philosophies.

Information flows play a critical role in modern supply chain management (Pereira 2009) and the integration of information flows can provide significant improvements (Madenas et al. 2014). There is a wide range of information technology solutions that can support integration between supply chain parties, including web-based systems and decision support systems (Madenas et al. 2014, Eriksson 2015, Benton and McHenry 2010). Thus, the selection of the most fitting information technology to support the type of relationship is a strategic decision. This decision is hard to make since the availability of many specialised solutions that do not interact creates the problem of ''Isolated Islands of Information'', as described by Madenas et al. (2014). Vaidyanathan and Howell (2007) underlined the need of process change that permits the exchange of data between firms and systems. These systems can reach closer to their potential when they can support all stakeholders with standardised project management processes that include all the required information to plan, control and coordinate projects (Ahlemann 2007). Hadaya and Pellerin (2010) argued that these technologies are currently used for exchanges of technical documents, drawings and inventory information between the contractor and key suppliers. Furthermore, Pala et al. (2013) identified that, due to cost concerns, this information exchange mainly occurs with clients, rather than suppliers.

Pala et al. (2013) identified the following priorities for contractors regarding collaboration: supplier relationship management, strategic supplier selection, supply chain risk management, supplier development, supplier coordination, and client relationship management. But, as Lönngren et al. (2010) underline, "*All too frequently, participants performing necessary partial services view their role in isolation from the others and with no concept of working towards an optimisation of the project as a whole*". This means that not all participants are willing to collaborate in a closer manner. Additionally, there is a large amount of products and services provided by other parties which makes total supply chain collaboration unfeasible. This leads to the need to select the parties that are worth the effort to build collaborative relationships with. Brown et al. (2001) propose that these parties could be the suppliers of key components of the project. The contractor could benefit when sharing the responsibilities with selected team members (Nesan and Holt 1999). Benefits of collaboration include improved relationship, reduced cost, enhanced value, and increased satisfaction (Meng 2013). Bresnen and Marshall (2000) studied contemporary literature and found the following benefits from the adoption of collaborative practices: improvements in cost, time, quality, buildability, fitness-for-purpose and other criteria. Collaboration isn't achieved out of the blue or effortlessly, it a result of a carefully crafted plan. Poirier et al. (2016) performed a meta-analysis on collaboration and identified structure, process, agents and artefacts to be four core entities that mutually adjust under the conditioning of a fifth entity; context. This means that context is the most important factor in collaborative strategies.

Construction supply chain strategies dictate the way interaction with other supply chain partners is conducted and each party's responsibilities regarding the project. Collaboration in the supply chain can be short-term, focussed on a single project, or long-term, over a series of projects during a relatively long number of years (Bennett and Peace 2006, Cheng and Li 2001, Langdon and Consultancy 2006, Bygballe, Jahre and Swärd 2010, Meng 2013, Crespin-Mazet, Ingemansson Havenvid and Linné 2015). Contracts are the main document describing these interactions and transactions that may range from strictly formal to relational. The prior type of transactions do not deviate from the terms and conditions of the contract, whereas the latter include practices such as partnering, alliancing and integrative project delivery (Ning and Ling 2013). On the one hand, according to Isatto and Formoso (2011), formal contracting recognises the possibility of opportunistic behaviour without taking bounded rationality into consideration, on the other hand, relational contracting takes bounded rationality into consideration and expects cooperative attitudes in order to overcome any problems. The main difference between the aforementioned types of contracts is the existence of trust, and fair and transparent distribution of responsibilities and benefits in the relational contracts (Lahdenperä 2012). Relational contracting may extend past the construction phase to maintenance and demolition, for example public-private partnerships (Parker and Hartley 2003, Kumaraswamy, Anvuur and Rahman 2005, Zheng, Roehrich and Lewis 2008). One of the most extensively researched relational transaction concepts is partnering. As Lahdenperä (2012) explain, "*partnering is often used to describe the collaborative building project practice in general*". In some cases, for example Broome (2002), partnering is described as such a general concept that it covers project alliances as well, which leads to the need for an exact definition of the concept of partnering. There are a few definitions for partnering in the literature such as the following:

- "*Partnering is a management approach used by two or more organizations to achieve specific business objectives by maximizing the effectiveness of each participant's resources*" (Bennett and Jayes 1995).
- "*Partnering is the simple process of establishing good working relations between project parties*". (Chan, Chan and Ho 2003)

- "*Partnering is a project management approach to enhance project performance through a transformation of the traditionally confrontational construction culture to one that is based on trust and openness*" (Cheung, Suen and Cheung 2003).
- "*Partnering refers to long-term agreements between companies to cooperate to an unusually high degree to achieve separate yet complementary objectives*" (Construction Industry Institute 1991)
- "*Partnering as a structured sequence of processes initiated at the outset of a project that is based on mutual objectives and utilizes specific tools and techniques such as facilitated workshops, a charter, conflict resolution techniques and continuous improvements techniques*" (Lu and Yan 2007).

The last definition was deemed as the most complete definition by Eriksson (2010b) and is thus adopted in this work to. Partnering is thought to present advantages in quality, sustainability, safety performance, dispute resolution, human resource management, innovation, and reductions in time and cost (Eriksson 2010). Partnering is a learn by practice process (Bennett and Jayes 1998), that requires commitment of management resources at an early stage of the project and an initial investment to cover costs of workshop organisation, staff training, workshop review, task monitoring and evaluation, and new member training (Kaluarachchi and Jones 2007). In practice, during the execution of the contract the relationship evolves towards partnering as new rules and practices are mutually agreed upon by both parties and the original partnering contract often loses its importance (Axelrod 1984).

While in relational transactions, behaviours such as showing flexibility, availability to compromise on unclear issues, and information sharing are displayed by involved parties (Ning and Ling 2013). According to Reve and Levitt (1984), there are different transaction types that can lead to the choice of relational contracting or not, as seen in **Table 8**.

Table 8: Transaction types and contracting types (based on Reve and Levitt (1984))

Transaction frequency	Transaction investments	Preferred contracting type
Recurrent	Semi-specific or highly specific	Relational contracting
Low	Semi-specific or highly specific	Neoclassical contracting or trilateral governance
Cost efficient	High	Bilateral and trilateral governance

There are three types of relational agreements in the literature that have much in common: project partnering, project alliancing and integrated project delivery (Lahdenperä 2012). Project partnering is a single project management approach that involves two or more organisations that interact based on mutual objectives, an agreed method of problem resolution and an active search for continuous improvements (Bennett and Jayes 1995). "*Project alliancing is a method of delivering major capital assets where the owner and non-owner participants work together as an integrated, collaborative team in good faith, acting with integrity and making unanimous, best-for- project decisions, managing all risks of project delivery jointly, and sharing the outcome of the project*" (Department of Treasury and Finance (2010) as seen in Lahdenperä (2012)). Integrated project delivery involves a contract binding, at a minimum, the owner, design professional, and builder that shares risks and rewards depending on the success of the project (Cohen 2010). In order to achieve a partnering contract with a client that has never used such a procurement mode, there needs to be a "*high level of perceived project's functional challenge associated to a high level of* *relational congruence in the project network*" (Crespin-Mazet, Ingemansson Havenvid and Linné 2015) and a perception of partnering as a risk reducing method. In order to succeed in implementing a partnering arrangement in the supply chain, Briscoe et al. (2001) underlined the importance of the following wide skills: writing and reading skills; numerical and financial skills; design communications; client and contractor relationships; supplier communications; teamwork; planning and problem solving; and manual skills. Key features of all the aforementioned arrangements, according to Lahdenperä (2012), are the following: cooperative culture, team formation, administrational consistency, commercial unity, planning emphasis, teamwork premises, and operational procedures.

Entering partnering agreements with suppliers is considered as a way to solve many of the problems that trouble the construction industry, but in reality, not all construction sectors have adopted the philosophy at the same extent (Naim and Barlow 2003). Project partnering, if seen as an episode in a long-term relationship, results in higher interaction levels between project parties and any following attempts bear less risk since some of the required adaptations have been made (Crespin-Mazet, Ingemansson Havenvid and Linné 2015). The increased level of trust and related knowledge lays dormant in between projects (Hadjikhani 1996) until the need to maximise the effectiveness of resources through strategic partnering (Love et al. 2002) goes beyond a single project and aims for long-term benefits (Lönngren, Rosenkranz and Kolbe 2010). A basic precondition for partnering to succeed is that involved parties have compatible goals (Walters and Lancaster 2000). Larson (1997), in his study of real projects, correlated the use of partnering with improved measures of project success. Adopting long-term partnering leads to reduction of project times, improvements in quality and safety, better responsiveness to market changes, improved client focus and client satisfaction, and greater stability in workload (Bresnen and Marshall 2000). Ning and Ling (2013) performed an extensive literature review and identified twenty-one drivers (**Table 9**) for adopting relational transactions.

Table 9: Drivers for partnering adoption (adopted from Ning and Ling (2013))

Category	Drivers
Better cost outcome	reduction of total project cost
	reduction of risks or the mitigation of their influence
	reduction of the cost of changing partners
Better time outcome	reduction in time needed to deliver the project
	reduction in a public client's administration burden
Better quality	improvement in the quality of project
	improvement in the design
	achievement of better safety performance
Increased satisfaction	maximisation of resource utilisation
	response to a collaborative culture in a project
	provision of an integrated solution to improve efficiency
	response to public/social/end-users' needs
Increased competitiveness	response to competitors' actions
	improvement in an organisation's competency
	enhancement of an organisation's reputation
Better relationships	reduction of disputes during a project
	building of closer relationships with contracting parties
Future relationships	seizing of new market opportunities
	achievement of continuity for past relationships
Facilitating innovative efficiency	response to technology changes
	facilitation of creative and innovative approaches

Unlike traditional price-driven selection, partnering provides designers and contractors with flexibility to innovate and reach performance optimisation (Love, Irani and Edwards 2004). In the early days, the partnering concept was considered as a way to battle the fragmentation that plagued the industry (Bresnen and Marshall 2000). Although, initially, most of the attention was focussed on the client-contractor partnerships, literature has also researched partnering upstream the supply chain in recent years. One of the most common problems faced by companies implementing partnering is that the benefits of cooperation and cooperation itself are not achieved, which is attributed to a lack of understanding and know-how for partnering implementation (Saad et al. 2002; Eriksson 2010b). another common problem is that clients do not prefer adopting partnering practices due to their initial extra costs (Ng et al. 2002, Love 2002). Two studies by Ng et al. (2002) and Ning and Ling (2013), as seen in **Table 11** and **Table 10** respectively, present extensive lists of barriers and problems related to partnering adoption.

Table 10: Barriers for partnering adoption (adopted from Ning and Ling (2013))

Category	Barriers
Incompetence	lack of knowledge of relational approaches
Lack of experience in relational contracting practices	lack of training and guidance in a relational arrangement
	past negative experience of a relational arrangement
	misgivings about future relationships
	lack of experience in relational arrangements
Uneven levels of commitment	unenthusiastic participation of contracting parties
	lack of top management support (in each party)
	lack of acceptance by contracting parties of relational approaches as a long-term way of doing business
	lack of client's initiative in relational contracting practices
Misalignment among project team members	lack of common goals among contracting parties
Adversarial relationships	interpersonal/cultural clash (individual level)
	concerns about the opportunistic behaviours of other contracting parties
	incompatible organisational cultures among the contracting parties
Cost and time required to conduct relational transactions	high cost in adopting relational approaches
	time required to develop a relationship
Resistance to change	conservative industry culture inhibits changes and encourages preservation of the status quo
Lack of trust	lack of empowerment in the client's representatives
	lack of trust among the contracting parties
One-off nature of projects	client only has occasional need for project development
Adherence to rules and codes of conduct	public sector accountability concerns
	bureaucratic public client organisation
	stringent public rules, regulations and laws
	need to avoid possible allegations of corruption arising from close relationships between the client and other contracting parties

Table 11: Problematic issues in project partnering (Ng et al. 2002)

Category	Problem
All stakeholders specific	Lack of continuous open and honest communication
	Stakeholders not developing a ''win–win'' attitude
	Stake holders are not committed to the partnering arrangement
	Lack of intimacy in the partnering relationship
	Issues are allowed to slide and escalate
	Some partners are unwilling to compromise

Category	Problem
Client specific	Lack of empowerment in the client's controlling bodies
	Dealing with large bureaucratic organisations
	Controlling body's lack of technical knowledge
Contractor specific	Commercial pressures compromising the partnering attitude
	Lack of training and guidance in the project partnering arrangement
Project specific	Use of a competitive tendering arrangement inhibits flexibility
	Problems with drawings and specification
	Key subcontractors not included in the partnering process
	Partnering is not suitable for a particular project

The literature concludes that partnering is not to be used in every single project (Jashapara et al. 1997, Thompson and Sanders 1998B, Bresnen and Marshall 2000, Ng et al. 2002, Eriksson 2010), since in many projects parties do not share common goals to allow teamwork to thrive (Love, Irani and Edwards 2004). Alderman and Ivory (2007) underlined that the existence of a joint project office for partners is important in order to boost socialisation among personnel. Briscoe et al. (2001), Ng et al. (2002) and Radziszewska-Zielina (2010) identified twelve, fourteen and fourteen key elements of successful partnering respectively. In spite of the obvious overlaps, it becomes apparent that partnering is a very complex concept that requires a highly specific combination of tools, techniques, processes and practices (Bresnen 2010). Eriksson (2015) provided the following four dimensions of supply chain integration in order to manage partnership implementation: strong integration through many integrative activities and technologies; wide scope of integration through broad partnering teams and group incentives; long integration duration through early involvement and long-term contracts; deep integration of top managers, end-users, and blue collar workers. In cases of first partnering attempts occurring in projects that are characterised by complex technology, high uncertainty and difficulties in performance assessment, trilateral governance that involves competent third party agents may be more suitable (Reve and Levitt 1984). The latest improvements in information technology are crucial in any attempt to partner since they support open and transparent communications and information sharing (Bresnen and Marshall 2000).

4.2.2. Determine supply chain management strategies process model

The “Determine supply chain management strategies” function (**Figure 11**) is the first management function in the model and aims at outlining the strategies for each of the other eight functions of the model. Strategies should be formulated for each and for all functions simultaneously in order to avoid conflicts between strategies. The focus of the strategies should be on integration of processes, flows, systems, and actors (Bankvall et al. 2010). Micromanagement decisions are out of scope of this function since they are hard to anticipate and are left to the operational level (Isatto and Formoso 2011). There are three processes in this function, namely “Determine strategies for management processes”, “Determine strategy for support processes”, and “Determine strategies for core processes”. Especially when the strategy aims towards supply chain integration, it is important to examine strategies related to purchasing complexity, demand uncertainty, product variety, and the decoupling point (Eriksson 2015). Sub-optimisation is a common problem and, thus, a holistic approach to supply chain management that includes, among others, the selection of suppliers, the location of facilities and the choice of distribution channels must be followed (Christopher, Peck and Towill 2006).

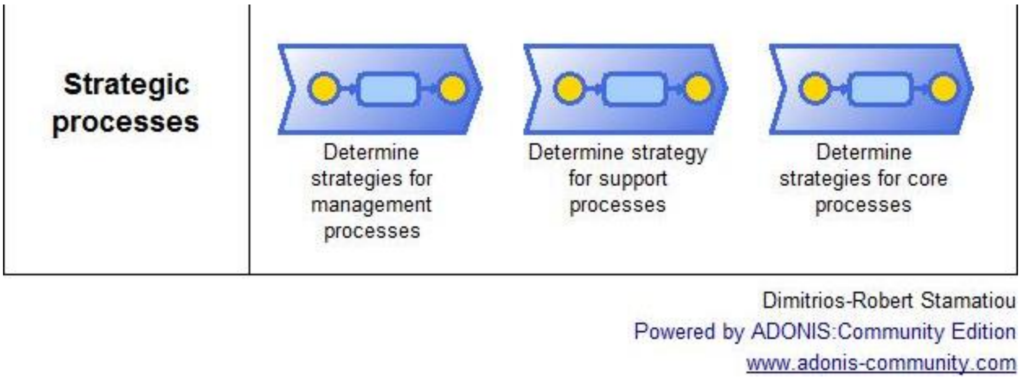

Figure 11: Determine supply chain management strategies function

The first process is "Determine strategies for management processes", as seen in **Figure 12**, and it concerns the selection of strategies with which the contractor will interact with its' environment, namely clients and suppliers. The type, form, length and intensity of the relationships with such parties are affected by the following factors: mutuality, duration, process nature, and context dependence (Holmlund and Törnroos 1997), with duration being of critical importance in terms of integration across projects (Eriksson 2015). Relationships are developed at the project, regional, division, and corporate level when the contractor comes in contact with other parties for the purpose of purchasing and procurement (Bemelmans et al. 2012). Alshawi and Ingirige (2003) identified middle-level management as where the highest level of interaction occurs. Different levels of cooperation develop different relationships that may extend from arm's-length relationships at low levels of cooperation to the development of project team identification by personnel rather than corporate identification in high levels of cooperation (Eriksson 2010). At this point, it is important to highlight the need of "*a clear record of with who a business interacts and what the attributes of that relationship are*" for any business and operations strategy to succeed at developing long-term relationships (Pala et al. 2013). The first task is to 'Identify key client segments to target'. According to Tran et al. (2012), "*client strategies provide important context to which construction strategy must react*". Low-cost advantage through cost reduction and differentiation of services/product to maximise client's satisfaction are the two main types of competitive strategies followed by construction companies (Dikmen and Birgönül 2003). Ling et al. (2005) promote the differentiation strategy as the most fitting strategy for construction companies. Through this strategy contractors can offer clients the gained discounts from the fact that a small number of firms supply each other with larger work volumes (Love, Irani and Edwards 2004). Additionally, concerning client strategies, when complexity, customisation, uncertainty, duration, and time pressure increase in a project, then more cooperative forms of governance become the focus (Eriksson 2008). To reach a partnering agreement with the client though, much depends on how the client perceives the project's functional challenge and the relational congruence in the project network (Crespin-Mazet and Ghauri 2007). The second task, 'Identify client service needs', concerns the strategies to be followed in projects where the contract binds the contractor for phases following construction. These strategies are out of the current study's scope, but the task is added since such strategies greatly impact the relationship between the contractor and the other implicated parties. Next, it is important to 'Determine role of new project development in total strategy'. As Love et al. (2004) underline: "*It is during the design process that the most important decisions are made*". "*Traditional design management practice focuses on the more general task-level management and scheduling*" (Lahdenperä and Tanhuanpää 2000). In this task, depending on the type of project under development, the level of client and supplier involvement is determined in order to complement internal knowledge, reduce overall risks and identify new markets or technologies (Rogers, Lambert and Knemeyer 2004). For example, as Naim and Barlow (2003) highlight, in simple and repetitive projects such as house-building close collaboration between parties can improve buildability. In cases of one of a kind projects that are characterised by high complexity, customisation, uncertainty, and time pressure, Brown et al. (2001) propose the integration of design and construction (concurrent engineering), which can provide a boost to good cooperation during project execution (Eriksson 2010). Even in more mediocre situations though, collaboration in early stages of the project can provide significant benefits for all parties (Eriksson 2010, Eriksson 2015, Bankvall et al. 2010, Love, Irani and Edwards 2004). Despite the benefits that stem from such practices, in order to avoid information congestion and additional management costs, Johnsen (2009) proposes the integration of the "right suppliers". The final task in this process is to 'Identify key suppliers to partner'. This is important as replacing key suppliers can be very expensive and directly impacts project progress (Winch 2001). Pala et al. (2013) describe four management approaches to relationships with suppliers: 1) it is sufficient to monitor the interface between the construction site and Tier 1 suppliers in transactional relationships; 2) control should extend up to Tier 2 suppliers in series of transaction relationships; 3) early supplier involvement in the construction process is the main strategy in project collaboration relationships; 4) management up to Tier 4 suppliers is required in long-term strategic partnering relationships in order to reap all related benefits. In the last case, it is critical to involve key subcontractors in the partnering team (Eriksson 2010). In order to identify the best suppliers with which to partner, prequalification criteria should be set based on the unique entities of the relationship (Pala et al. 2013). Another way of selecting a key supplier to partner with is limited bid invitation, although it is not always applicable due to public procurement acts (Eriksson 2010). Nonetheless, irrelevant to the type of relationship selected, decision on reactive or proactive relationship management has to take market and supply chain options into consideration (Cox, Ireland and Townsend 2006A).

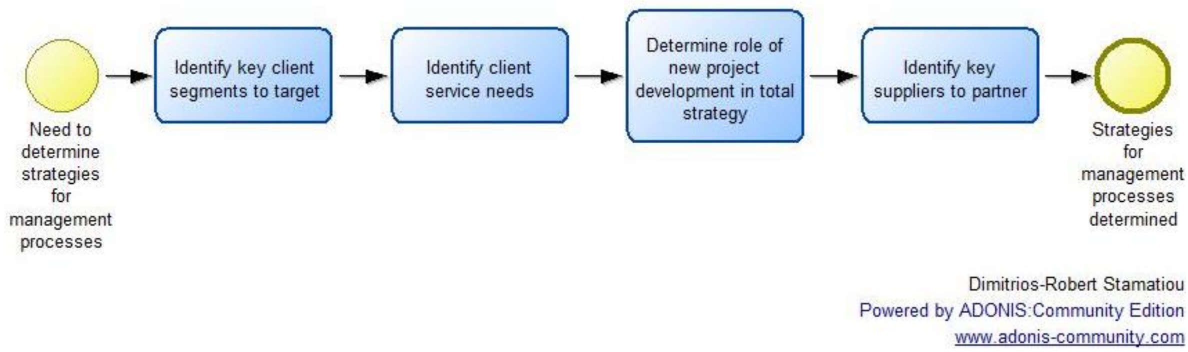

Figure 12: Determine strategies for management processes

The second process is "Determine strategy for support processes" as seen in **Figure 13**. A critical element in lean construction is that of performance measurement (Freire and Alarcón 2002), but performance measurement in construction supply chains is a daunting, yet important, task (Wickramatillake et al. 2007). Many authors (Elliman and Orange 2000, Gibb 2001, Sánchez-Rodríguez et al. 2006, Bankvall et al. 2010) support that it is essential to use standards in order to execute tasks such as systems alignment, quality assurance, innovation and risk reduction. The first task is to 'Determine need for maturity level analysis'.

The level of process maturity should be analysed in order to identify the types of measurement that can provide the best results for the current level of maturity. This is a strategic decision since process maturity analysis is a complex task that will consume resources but yield results in the long-term. The next task is to 'Determine key KPI's to monitor selected strategies'. Performance in the construction industry is dependent on many variables and unpredictable factors such as performance of parties, resource availability, environmental conditions, and contractual relations (Mirawati, Othman and Risyawati 2015). Performance measures include both subjective and objective indicators and carry all the advantages and disadvantages they have (Allen et al. 2007). There are tools such as the Construction Best Practice Programme (Department of Environment Transport and the Regions 1998) that provide companies in the construction industry with benchmarking guidelines and key performance indicators. These indicators can be used to compare client satisfaction, productivity, cost, safety, and other criteria against the rest of the industry (Briscoe, Dainty and Millett 2001). Alzahrani and Emsley (2013) identified nine clusters that need measurement: safety and quality, past performance, environment, management and technical aspects, resource, organisation, experience, size/type of pervious projects, and finance. It is important to set targets and then evaluate performance at a post construction phase in order to identify the wrongs and rights in each project (de Wit 1988). For example, Arbulu et al. (2003) identified an "*order of magnitude of 5% for value-added time over lead time*" in their study which indicated the existence of opportunities for process improvement.

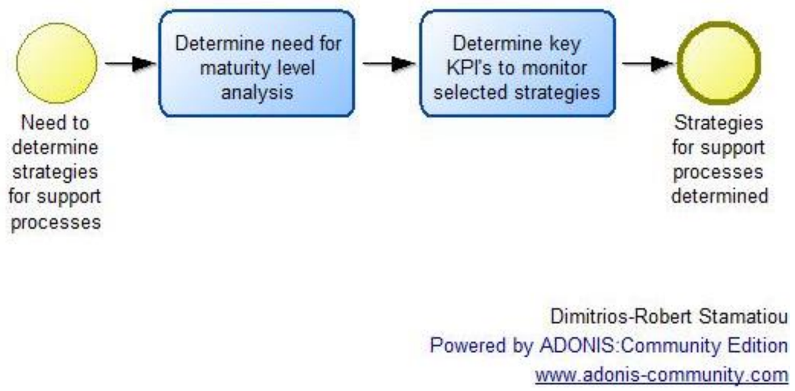

Figure 13: Determine strategy for support processes

The last process of this function is "Determine strategies for core processes" as seen in **Figure 14**. The first task is to 'Determine focus of demand management and its effect on company resources'. "*Demand management is the process an organization puts in place to collect new ideas, new projects, new needs, and so forth*" (Romano, Grimaldi and Colasuonno 2016). However, companies in the construction sector respond poorly to short-term changes in demand (Naim and Barlow 2003). This means that a well thought strategy for demand management can provide a competitive advantage to those who plan ahead. In construction, each project can be considered as a single product and the sum of the running projects and projects to bid for represent a portfolio for each contractor. According to Romano et al. (2016), management of the demand portfolio includes: definition of the strategy and objectives of the next years; selection of a list of components to achieve these objectives; implementation of objectives; performance measurement of each and all components; review of component planning and strategy/objectives; and verification of the expected benefits realisation in order to redefine the strategy and targets for the future. The next tasks, to ‘Determine work package management strategies based on client requirements’ and to ‘Determine level of flexibility for construction flow strategies’, are separate but highly interconnected. Each work package has its own supply chain and the coordination of the supply chains of all the work packages is the secret to project success (Arbulu et al. 2003, Fearne and Fowler 2006). It is of great importance to be able to develop and maintain effective project plans and schedules. This involves the drawing of alternative strategies for each project type that consider the aspects of tactical variable selection and related values and plans for different levels of project definition at all project stages describing conditions different than to those anticipated (Tran, Russell and Staub-French 2012). Disruptions in the supply of resources to the site cause, on the one hand, delays in site operations and, on the other hand, additional storage costs for the supply chain (Brown et al. 2001). Vidalakis et al. (2013) identified that, from an operational viewpoint, the adoption of supply chain management principles in the construction industry have been based on lean and agile construction concepts. A typical example is the use of Last Planner and Just In Time in order to deliver materials to confined construction sites (Brown et al. 2001). In his works, Christopher (Christopher 2000, Christopher, Peck and Towill 2006) connects demand variability with the selection of lean or agile strategies. In construction both strategies must be implemented. Demand at the project level is relatively stable and forecasted, thus lean practices can provide many opportunities. Demand at the portfolio level is highly volatile, thus agile practices present the opportunity for better responsiveness in a turbulent and unpredictable market. Tasks and activities at the construction site may have different interdependencies, such as sequential, pooled or reciprocal, that call for different levels of coordination, collaboration and management between the involved parties (Bankvall et al. 2010). In addition, project supply chains have to be synchronised (Crowston 1991) since they may share resources such as personnel (Dubois, Hulthén and Pedersen 2004). Project execution strategies have to be volatile enough in order to accommodate problems such as procurement delays, change orders of many origins, issues with the pace of work caused by changes in economic and market conditions, and other issues, by applying changes through different methods, modifications to work sequencing, number of work phases, work type as a work zoning tool, selection of resources and their amounts, off-site fabrication and changes in work week definition (Tran, Russell and Staub-French 2012). Finally, the task ‘Determine claims management strategy for each client/supplier segment’ aims to determine the importance of claims and contract cancellation management process in the supply chain, the project itself and the profitability levels. Not all projects need to be seen in an adversarial manner and claims strategies need to be volatile depending on the client, the contract and previous relationships with the implicated parties.

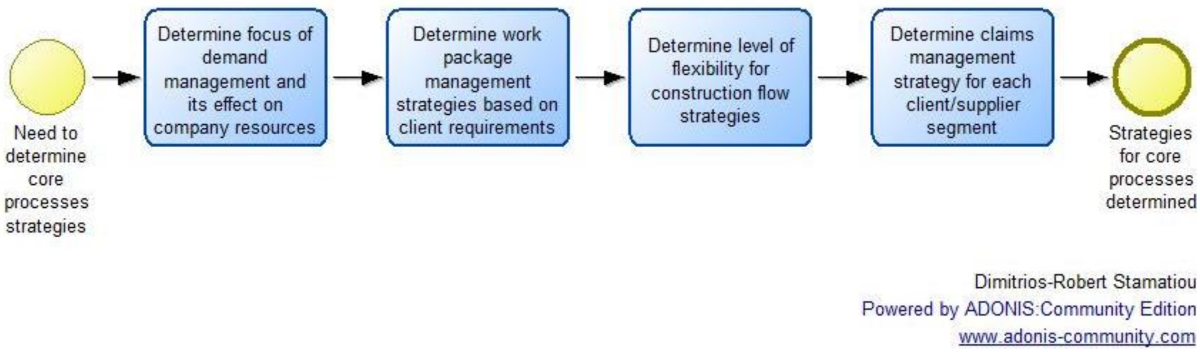

Figure 14: Determine strategies for core processes

4.3. Client relationship management

4.3.1. Analysis of client relationship management

A construction project is the product of the construction process and the entity (person, organisation, etc.) that had assigned or will buy the end project is the client[4]. A client initiates the purchasing process and formulates specific requirements that the contractor has to cover (Bildsten and Manley 2015). Clients are diversified in their nature, complex in their procurement methods, varied in their knowledge of the industry and seek value for money in their transactions with increasing concerns in sustainability and the environment (Preece et al. 2015). It is the clients' decision to procure construction works and to select the procurement method which, ultimately, affects the project supply chain (Briscoe et al. 2004). This is the main contributor to some of the construction industry characteristics. The end product is tailor-made, fixed and immobile and the client 'buys' the product based on a concept of it and not the actual product (Dulaimi 2005). In many cases though, clients are not an individual, rather they are a group of people or an organisation (Bertelsen and Emmitt 2005) which makes decision making on the clients side a slow and painstaking process since there may be competing sub-groups in the mix (Cherns and Bryant 2006). There are actually some discrepancies in the industry and academia on how clients are viewed. For example, Reve and Levitt (1984) describe interactions with clients as having high intensity but low frequency with previous trade relationships having low impact, whereas Bresnen and Haslam (1991) describe the industry as having a considerable number of regular clients with considerable experience in the projects they assign. The main problem in the industry is how to establish and maintain collaboration with the clients due to the contract based interactions, the lack of relationship management and personal attitudes of actors in the industry (Kadefors 2004, Bresnen 2007, Rose and Manley 2010, Laan, Voordijk and Dewulf 2011, Boes and Dorée 2013). Clients' needs are the most important feature of the transaction. Strategic choices of the client regarding the management of the project affect project performance (Bresnen and Haslam 1991). Not all clients have the same expectations (Love, Skitmore and Earl 1998) and the level of expectations of each client is a function of word-of-mouth, past first-hand experiences and direct interaction with contractors (Maloney 2002). In recent years, client expectations have been rising which increases competitiveness between contractors (Dulaimi 2005). Contractors (in the UK) have been criticised for their failure to fulfil client needs (Latham 1994, Egan 1998). Client needs vary considerably between different clients, different projects of the same client, and over time (Maloney 2002). Contractors, regardless of their size, lack formal strategies and processes related to client management (Nguyen et al. 2008) and despite communication with the clients being critical, there is no complete skillset to manage such tasks (Sebastian 2011). It is of great importance to define the concept of a 'client' in order to establish a relationship management process. Preece et al. (2015) provided the following definition: "*A customer (also known as a client, buyer, or purchaser) is the recipient of a good, service, product, or idea, obtained from a seller, vendor, or supplier for a monetary or other valuable consideration*". This definition is too general to picture the construction client. The British Property Federation ((1983), as seen in Tzortzopoulos et al. (2009)) provided the following definition: "*clients have been defined as the person or firm responsible for commissioning and paying for the design and*

[4] In the following text, based on their definition in the Collins dictionary (Collins 2017), the word 'client' is preferred to 'customer' for use in the construction setting and 'customer' is only used in cases of broadly used terms such as 'customer service'.

construction of a facility". This definition, although focused on the construction industry, fails to take into consideration the true nature of all clients. Construction clients can be complex and their characterisation could be puzzling for managers. As seen in **Table 12**, there are many possible ways to categorise a client in the construction literature. Although many categorisations seem like a client can be characterised by one of two extremes, there are categorisations that seem to be more of a range. For example, Boyd and Chinyio (2006) add the 'partially informed' category to the experience level element and the 'mixed' category to the financial sector element. Additionally, Cherns and Bryant (1984) underline that the environment within which the client operates is one of the most important factors in the clients behaviour. This means that there cannot be one universal effective definition for a construction client, but a set of parameters that have to be considered when describing a client.

Table 12: Categorisation of clients in literature (based on Tzortzopoulos et al. (2009))

Authors	Categorisation	Differentiation element
Darlington & Culley (2004)	Identifiable vs. virtual	Problem specificity
Franck & Zeisel (1983)	Paying client vs. end user	Source of cash flow
Edmondson (1992)	Apparent vs. end user	User
Higgin & Jessop (1965); Masterman & Gameson (1994)	Sophisticated vs. naive	Experience level
Hillebrandt (1984)	Continuing vs. one-off	Job recurrence
Hillebrandt (1984)	Public vs. private	Financial sector
Cherns & Bryant (1984)	Unitary vs. pluralistic	Amount of projects in portfolio
Masterman & Gameson (1994)	Primary vs. secondary	Client business
Boyd & Chinyio (2006)	Large vs. small	Organisational size

In order to analyse how client relationships can be managed, it is important to understand how clients view the construction industry. Baldry (1997) studied the image clients, participants and contractors had of the construction industry and found that clients view, from first-hand experience, the construction industry as: reasonably effective and productive; holding a more positive view of the industry than contractors; occasionally inaccurately described in media; lacking post-completion support; holding a culture of conflict; puzzled by uncertainty over time, cost, and quality standards; having the same ethical standards as other industries; being inconsistent towards environmental responsibility; avoiding the use of the latest technical and scientific developments in complex problems despite the ability to do so. Simon ((1965) as seen in Bresnen & Haslam (1991)) support that "*clients rely on 'tried and tested' methods, seeking a satisfactory, rather than optimal, solution to the project management problem*". Traditional contracting practices are preferred by one-off clients that rarely require construction services (Akintan and Morledge 2013). Baldry (1997) found that clients and contractors do not agree on what methods of construction services promotion are most effective. There is an up-side though in the finding of Love et al. (1998) that "*similar clients with similar project requirements may have similar and consistent priority ratings*". Clients can be profiled by analysing their requirements in speed, certainty, flexibility in accommodating design changes, quality, complexity, risk allocation/avoidance, responsibility, price competition, disputes and arbitration (Skitmore and Marsden 1988, Singh 1990) and different procurement methods may be used in each case (Love, Skitmore and Earl 1998). But the fact that a project is completed within the time and cost limitations does not mean that the contractor will work with the specific client again in the future (Maloney 2002). Contemporary clients expect much more than the delivery of the construction product. According to a study conducted by Lönngren et al. (2010), more than half of the clients would be willing to pay for construction companies to provide post-construction services.

Next, it is important to describe the concept of client relationship management in construction before further analysing the literature. Edum-Fotwe et al. (1996) found that contracting companies did not include any mention of clients in their strategies or mission statements. This behaviour is still around in recent years due to the passive influence of professional advisors and consultants on the construction product and poses the main inhibitor to the improvement of development processes in the industry (Dulaimi 2005). It is typical of clients in the industry to request products that perform the same function, with higher quality and lower costs leading most contractors to follow a cost-leadership strategy. Contractor selection can occur, on one extreme, for a single project based strictly on price irrespectively of other qualifications or, on the other extreme, for multiple or recurring projects based on many other factors besides price (Reve and Levitt 1984). This makes for a very diverse client base. Additionally, it is common to find conflicts of interest in the contractor-client relationships since their objectives differ. In contemporary construction markets, the separation of ownership and occupation concepts, increase of corporate clients and continuing clients have caused traditional thinking in the construction industry to change (Newcombe 2003). Traditionally, relationships between the contractor and the client are described by intricate contracts (Reve and Levitt 1984) but contracts cannot provide solutions to all problems that may turn up during project execution (Manu et al. 2011). Arm's-length relationships do not require much support since their opportunistic nature means that the client and contractor will not meet in future projects. But contractors are slowly realising that maintaining a good relationship with their clients can be good for business. Having said that, the creation of a client relationship strategy requires that the contractor has mastered processes, people and technology at the business level and defined the relative benefits, risks and costs (Preece et al. 2015). The contractor interacts with the client through the employed personnel that executes the set processes with the use of the available technology. The interaction with clients requires intelligence generation (monitoring of competitors, technology, regulations, and legislation), dissemination of the generated intelligence, organisation-wide responsiveness, and feedback collection for improvement and impacts both the design and construction along with the clients' needs (Dulaimi 2005). According to Boes and Holmen (2003) there could be four types of interface (standardised, specified, translation, interactive) based on the involvement of the client and contractor in the design/engineering of a product and it is really important to recognise the correct interface for the exchange to roll smoothly. Almost none of these exchanges are simple and require high coordination efforts among both sides (Isatto and Formoso 2011).

It is common practice in construction companies to ignore monitoring clients' needs (Smyth 1999). For example, Anttila et al. (1999) found that more than half of Finnish construction companies never collected feedback from their clients. It is not only required by the contractor to identify a client's need, the contractor must also identify all requirements present in order to effectively fulfil them. This means that the relationship between the two sides must be managed effectively and efficiently. Smyth ((2000) as seen in Smyth et al. (2009)) listed the following relationship marketing tenets: developing close relationships to improve client and stakeholder understanding; developing services that match expectations; delivering services to engender client and stakeholder satisfaction; increasing long-term maintenance of relationships to induce loyalty, hence repeat business and/or referral business; increasing the value of the firm in the market to its owners. Despite the complexity of supply chain relationships, Meng et al. (2011) infer that improvement of relationships requires measurement. But before a measurement system can be devised, the contractor has to identify who is the actual actor on the organisation’s behalf. This actor is a member of staff and any attempts to create a client focused environment come down to the staffs acceptance and commitment to change (Dulaimi 2005). Smyth and Fitch (2009) listed the following benefits of adopting a client focused strategy: increasing repeat business and referral opportunities derived from improved client loyalty; increasing profitability through adding relationship and service value; and reducing sales plus other transaction costs. These benefits are not to be found in all relationships though. For example, Ning and Ling (2013) describe how open tendering is still used in public projects in order to avoid being seen “*as having hand-in-glove which may suggest cronyism*”, a fact that impedes the creation of long-term relationships along with depriving both sides from its benefits. Long-term relationships can lead to the creation of informal control mechanisms which Badenfelt (2010) identified as a prerequisite of trust creation and sustainment. Trust is a broadly studied subject in social sciences. There have been many studies (Bennett and Jayes 1995, Naesens, Pintelon and Taillieu 2007, Lau and Rowlinson 2010, Lopez-fresno and Savolainen 2011, Manu et al. 2011, Xu and Smyth 2015, Manu et al. 2015) on trust in the construction industry and its effects on construction partner relationships and projects. Trust is connected to improvement of organisational culture through cultivating fairness (Mayer, Davis and Schoorman 1995), better working environments (Mayer and Gavin 2005), commitment and effective inter-organisational communication and cooperation (Talay and Akdeniz 2014). Xu and Smyth (2015) add that trust is an appreciated foundation for business relationships that leads to long-term benefits for both parties by effective communication, relation and important knowledge. Trust between the client and the contractor can lead to positive behaviour such as problem and deficiency correction without accusations and claims for compensation (Manu et al. 2011). Trust is inextricably connected to the function of both formal and informal control systems (Cristina Costa and Bijlsma-Frankema 2007). Das and Teng (2001) describe how decisions on the correct governance mode relate to perceived hazards of a relationship and Poppo and Zenger (2002) underline the fact that these decisions are heavily related to the level of trust between parties.

Trust has also been cited as a success factor for partnering attempts (Poppo and Zenger 2002) because it allows relational governance based on agreed upon processes, values and norms to succeed (Manu et al. 2011). Corley et al. (2001) support that client integration is required in order to adopt their changing needs in design, and the adoption of partnering can prove to be a big step in that direction. There are plenty of tools to assist clients and contractors in the adoption of partnering practices, such as the ones described by Larson (1995), Ellison and Miller (1995), and Thompson and Sanders (1998) and to assess their readiness to adopt such a tool (e.g. Meng et al. 2011). Other forms of long-term collaboration between clients and contractors are alliances and framework agreements. Alliances require additional procurement time compared to other procurement methods but provide greater certainty of outcome in larger projects, maximise project performance for the clients and improve teamwork and behaviour, financial engineering, scope definition and design, cost accountability and project performance and delivery (Rowlinson 2005). Framework agreements are alliances between clients and contractors that replaces many commercial exchanges with a single long-standing relationship (Tommelein, Ballard and Kaminsky 2009). Despite their non-binding nature, clients receive dedicated supply chains in exchange for construction activities at a standard pricing scheme without the interference of non-participating parties to the arrangement (Tennant and Fernie 2012). In some cases, a niche governance form is used in these arrangements named "clans" (Tennant and Fernie 2012). Clan governance acknowledges the commercial viability of relationships while emphasising social integration, trust and community of practice (Ouchi 1980) and was described by Ouchi (1981) as an "intimate association of people engaged in economic activity". In her study, Carlsson (2008) found that close relations with clients and the ability to react to clients' needs where considered critical to business performance by all suppliers no matter their size. Closer collaboration between the client and the contractor leads to many benefits and a few downturns that have to be avoided. Gray ((1989) as seen in Boes & Dorée (2013)) described the following characteristics of cooperative problem-solving: shared problem-solving; shared search for facts; underlying interest in workable solutions; satisfactory outcome for all the parties; integration of interests; and, integrated collaborative negotiations. Other benefits of collaboration include better solutions for clients than what where initially conceived and open atmosphere between client and contractor (Boes and Dorée 2013). Open atmosphere can have the adverse effect of hampering the much needed critical attitude and have a negative influence on process efficiency (Boes and Dorée 2013). Eriksson (2015) identified four dimensions for successful supply chain integration in construction, namely strength, scope, duration and depth of integration. These dimensions have to be carefully studied before any attempt of a closer collaboration such as a partnership. Modern attempts for closer collaboration have more tools to support the day to day processes of such endeavours. Advancements in technology are aiding partnering attempts by creating progressive socialised trading environments (Adler 2001).

The contractor is evaluated by the client for the level of service provided. In the manufacturing industry, customer service is "*the output of the logistics fraction and the key to integrating marketing and logistics*" (Lambert 1992). Making an educated assumption that the finished project is the same as a finished product, the same can be said for customer service in construction. As a satisfied client will buy a consumer product again, Nguyen et al. (2008) found that high client satisfaction in construction increases repeat business and market share in the homebuilding market. Communication with the client is considered the most important factor of good service which allows the building and improvement of relationships (Maloney 2002, Nguyen et al. 2008). Maloney (2002) listed, along with communication, the following factors in contractor behaviour that affect the perceived service level by the client: access, competence, courtesy, credibility, reliability, responsiveness, security, tangibles, understanding/knowing the client. But clients can't really be objective when judging the contractor. As seen in **Table 12**, depending clients may not even be the end recipients of the service or may not be involved directly in the oversight of the construction process. This means that based on word of mouth, personal/corporate needs, and past experience, the client develops an expectance for the service level for each factor referred to by Maloney (2002) that leads to a perceived service level which differs from the actual service level. Service is tightly related to the perception of quality and client satisfaction. Again, quality is not an objective criterion and it depends on the expectation of the client against what was finally delivered. For example, Craig et al. (2010) examined the housing sector and identified two types of quality: technical and functional. Technical quality related to features that the client could not evaluate (Kang 2006) and functional quality related to the finishing and operability of the house. In many cases, technical quality may be high due to legislation enforcement and functional quality may be low leading to low client satisfaction. Additionally, perceived quality and service level are affected by the attitude and behaviour of contractor staff (Ferguson et al. 1999). Gunning (2000) proposes that the quality concept is not static in the construction industry and that it must be managed to match changing client expectations through time. Soetanto and Proverbs (2012) identified forty-eight criteria through which clients evaluate their satisfaction with the contractors' performance, out of which "*past performance of the contractor in terms of cost, time and quality*" and "*health and safety, quality control, and the variations caused by contractors*" where particularly important. Elsewhere, Suprapto et al. (2015) identified that there is a relationship between the perceived quality and the early involvement of clients and contractors in the design phase through to the delivery of the project. In the case the contractor is involved from the design phase, it is easier to asses and fulfil the clients' needs through better decision making during the construction phase (Skitmore and Mills 1999). Client satisfaction is a complex concept that depends on the type of project under question. For example, along with satisfying the clients' need, Larsson and Simonsson (2012) listed the following elements associated with client satisfaction in road projects: shortened construction time, information about disruption, and minimising traffic disruption during construction.

"*Integrated information systems and strategic alliances/partnerships [will] play an important role in achieving the desired levels of service performance*" (Lambert 1992). Attempts such as partnering, alliancing and other forms of relational contracting that aim at developing a collaborative relationship have common characteristics such as: aligned goals and interests, open and honest communication, mutual commitment and trust, long-term orientation, and joint problem solving (Suprapto et al. 2015). Adversarial relationships are no longer in favour, despite being practiced by many firms in the industry. Practicing closer collaboration requires sharing team responsibility in an attempt to improve relationships. These attempts require the formation and governance of effective team working (Suprapto et al. 2015). The most important factor for client friendly practices is organisational readiness through the development of a relative business strategy that can generate benefits for both parties (Hansotia 2002). A client friendly approach requires that certain technologies (Client Relationship Management – CRM) are used (Hendricks, Singhal and Stratman 2007). In such an endeavour, it is imperative that systems and business processes are integrated in such a fashion that supports flow of information from the client (Sear et al. 2008) and both parties have to develop an appropriate set of relational attitudes (Suprapto et al. 2015). In addition to the client focussed strategy, obtaining top management commitment, designing an appropriate organisational structure, adopting a fitting organisational culture, and using well defined success measures are important for positive results to appear (Sear et al. 2008). In particular, top management commitment is regarded as crucial for the success of CRM adoption (Kennedy, Kelleher and Quigley 2006, Sear et al. 2008). No blame culture, open and honest communication, and mutual respect between parties in addition to integration practices such as contractor's early involvement, shared team responsibility, joint working, joint risk management, recognition and rewards programs in contracts allow for higher project success chances in collaborative attempts (Suprapto et al. 2015). The rewards scheme is ambiguous as there are reports in the literature such as Baldry (1997) and Boes and Dorée (2013) that found them to have no effect. With contractors involved at the early stages of project development, client needs are assimilated into the design more efficiently and performance levels can be measured and improved (Lee, Cooper and Ghassan 2000). Such benefits can be obtained by the joint use of analytical, operational and collaborative CRM technologies along with the use of BIM technologies and their capabilities (Preece et al. 2015).

4.3.2. Client relationship management process model

The "Client relationship management" (**Figure 15**) function is the second management function in the model and includes all the processes related with client selection, management, grouping, negotiation and satisfaction. Nguyen et al. (2008) studied the concurrent literature and found that client service is considered a key management function in the house-building industry. This function expands client service to client relationship management by introducing additional client related processes that cover all of the construction industry. Imhoff (2001; p.96 as seen in Sear et al. (2008)) "*proposed five critical success factors which appear to be recurring themes in the literature. These five factors are: 1. implement a customer-focused business strategy; 2. create a CRM-friendly organisational structure; 3. establish a CRM-savvy organisational culture; 4. ensure top management commitment; and 5. define CRM success measures - which are subsequently discussed*." The focus of a CRM strategy should be upon retaining existing clients through continuous contact, developing client value over long time scales with high emphasis on client service, and high commitment to meeting client expectations (Smyth et al. 2009). The described function is comprised of fourteen processes; five strategic and nine operational. This is based on Preece et al. (2015) who claim that "*the philosophy, tools and techniques of CRM in construction has both strategic and operational consequences*". The strategic processes are the following: "Determine client categorisation criteria", "Develop guidelines for the level of differentiation in the project/service agreement", "Develop guidelines for transfer of benefits from process improvement to the clients", "Develop processes for client response", and "Develop IT infrastructure for CRM processes". The strategic processes can be executed whenever required and with no specific order. The operational processes in the model are the following: "Group clients", "Prepare client account management teams", "Review client accounts and identify opportunities", "Negotiate client project/service agreements", "Practice client project/service agreements", "Event recognition", "Evaluate situation and implement solution", "Evaluate client satisfaction", and "Client relationship management performance measurement". The first four processes are executed before the contract for a new project is signed and the following four are executed after there is a signed contract. The last process can be executed after the eight previous processes or in parallel to each of them. In order to implement such an initiative as a CRM model, a thorough understanding of peoples' values, perceptions, feelings and motivations is required in order to ensure the acceptance of change (Sear et al. 2008). The importance of such a model can be seen through the following claim by Rowlinson (2005): "*Relationship management is more than a characteristic of project management; it is one of its key features upon which the successful accomplishment of the project is likely to depend*".

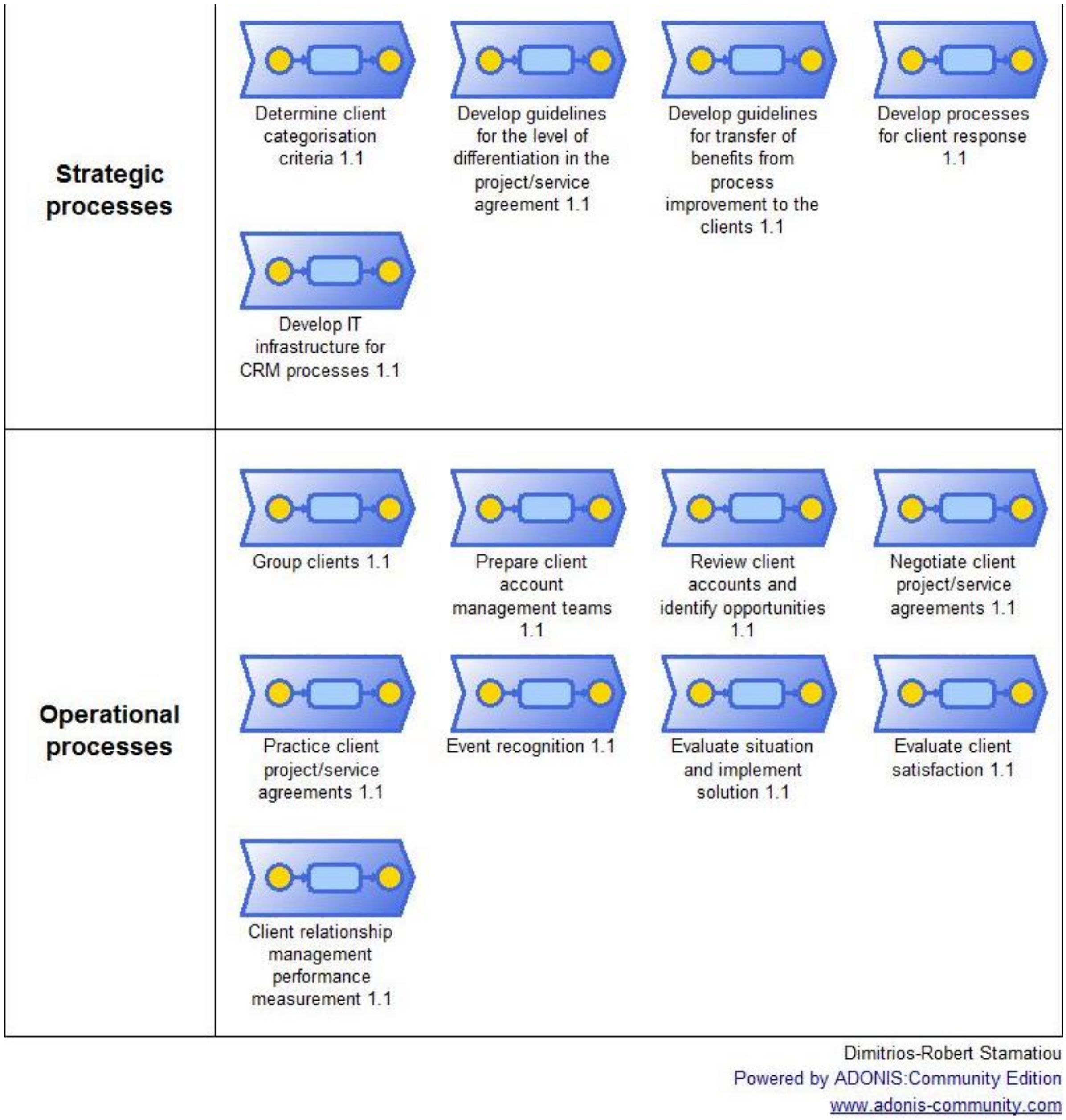

Figure 15: Client relationship management function

4.3.2.1. Strategic processes

The first strategic process is “Determine client categorisation criteria” as seen in **Figure 16**. “*It is crucial for a CRM strategy to identify the most profitable customers and direct their attention to attract those customers*” (Preece et al. 2015). The first task is to ‘Determine criteria for client categorisation’. Love et al. (1998) propose that client categorisation should be done using a two dimensional matrix describing the level of client market knowledge and technical knowledge of the construction environment. The Strategic Forum for Construction (2003) proposes the use of risk and value of the client as categorisation criteria into four client categories (Process, Assurance of supply, Leverage, Partnering). Tzortzopoulos et al. (2009) identified the following criteria for client categories: paying clients and users; level of experience of the client with construction; nature of the client organisation – sector in which it operates; type of clients’ business; size of the client organisation; and rate of change in the clients’ organisational environment. Lambert (2010) proposed the following criteria, having the manufacturing industry in mind, which could prove useful for the construction industry to: profitability, growth potential, volume, competitive positioning issues, access to market knowledge, market share goals, margin levels, level of technology, resources and capabilities, compatibility of strategies, channel of distribution and buying behaviour. The next task is to 'Determine client categories' based on the selected criteria. "*An appropriate classification for construction clients is necessary to provide clarity in terms of who the construction client is, their needs, their likely involvement with the process and support needed*" (Tzortzopoulos, Kagioglou and Treadaway 2009). The client category may be based on the nature of the client (public, private, mixed), their requirements in time, cost, quality, or other characteristics. Sear et al. (2008) proposed the creation of client categories based on client definition, client loyalty, and client value. All interviews conducted showed that both SMEs and large enterprises simply categorise clients into public and private clients and then focus on the project category. Next, the task 'Determine client category priorities' is executed. Contractors should identify the priorities of each client or client category in order to fulfil their requirements and to reach good client satisfaction levels (Maloney 2002). Finally, the task 'Determine contracting strategy for each client category' aims at creating a strategy that will govern contract negotiations with each client category. Keränen and Jalkala (2013) provide a framework for client value assessment that can be used to support the strategies set for each client category.

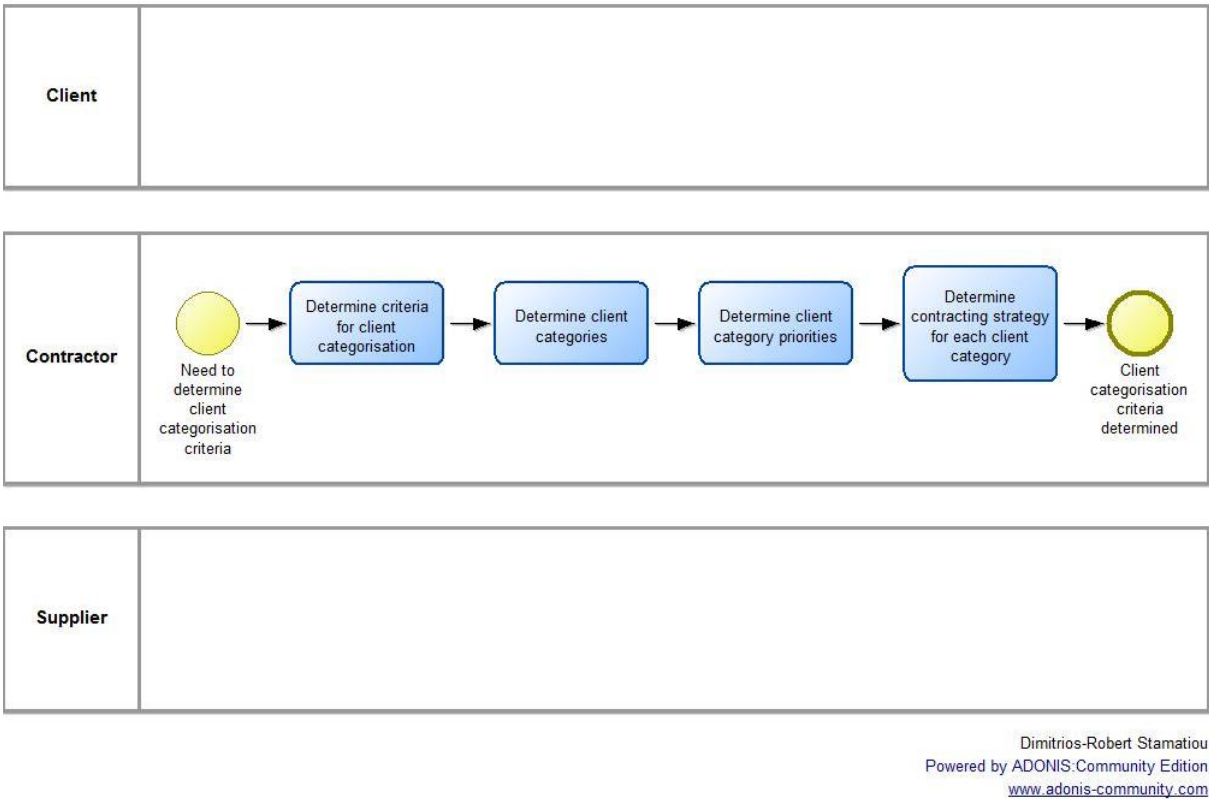

Figure 16: Determine client categorisation criteria

The second strategic process is "Develop guidelines for the level of differentiation in the project/service agreement" as seen in **Figure 17**. The first task is to 'Analyse client categories' and includes attaining information and evaluation of the potential clients and capturing and managing the potential clients' information (Preece et al. 2015). The next task is to 'Assess parameters affecting project agreements with clients'. Such parameters may include the level of production/service customisation and increasing the relationship with the high value clients (Preece et al. 2015). The ‘Analyse potential cost/profit for each type of contract’ task includes the analysis of contract types and their cost/profit levels. Next, the ‘Determine guidelines for agreements with clients’ task aims at providing a set of guidelines for contracts with future clients and managing available contracts. These guidelines may include decisions on enhancing the clients to make referrals, termination of non-profitable clients, and initiating interaction with the lost or inactive clients (Preece et al. 2015). Finally, it is advisable to ‘Develop alternative options for achieving project differentiation agreements with clients’ to include cases of less mainstream clients or client agreements.

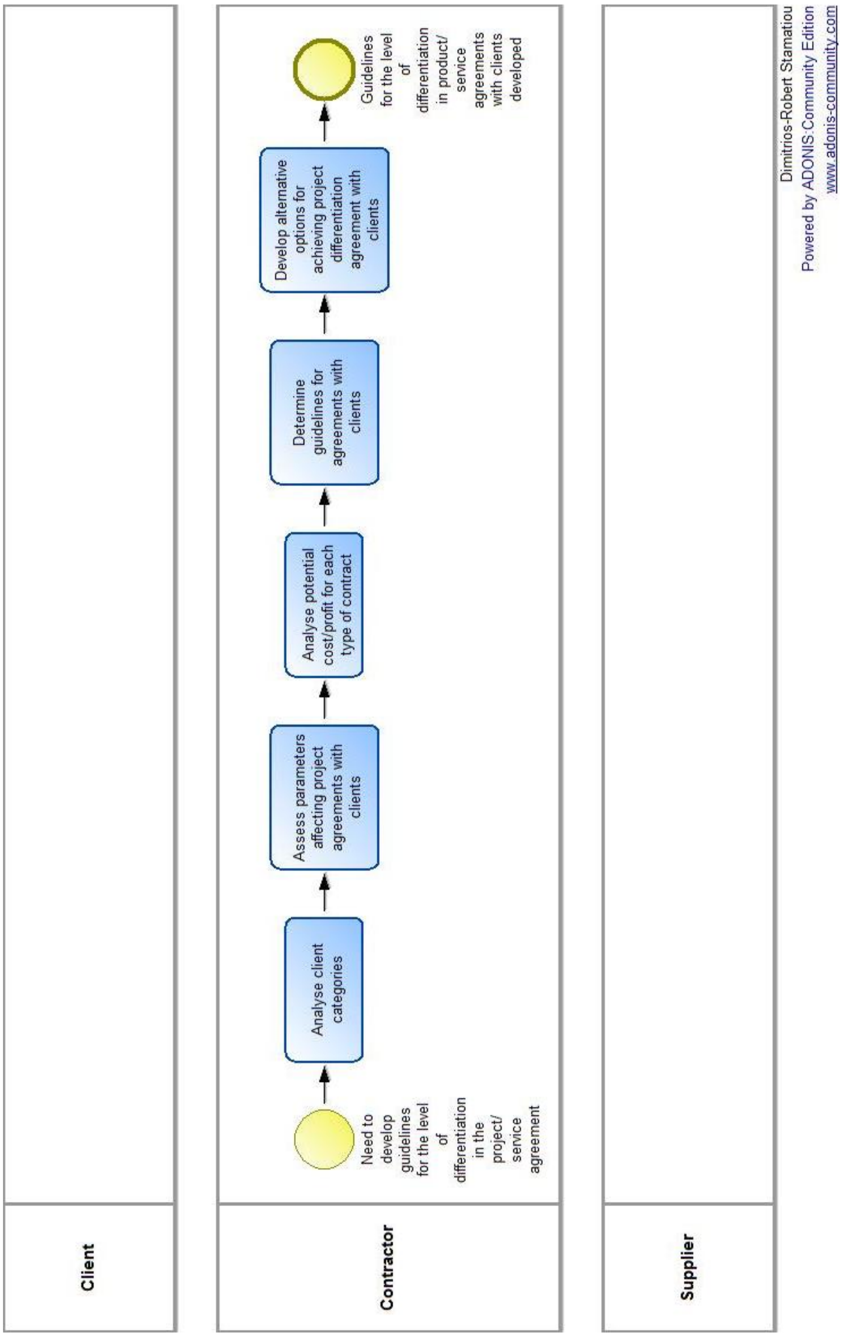

Figure 17: Develop guidelines for the level of differentiation in the project/service agreement

The third strategic process is "Develop guidelines for transfer of benefits from process improvement to the clients" as seen in **Figure 18**. According to Meng et al. (2011) construction companies can benefit from identifying key areas of existing relationships for improvement as these improvements will lead to performance improvements, reduction of conflicts and opportunities for collaborative working. The first task of this process is to 'Provide guidelines to recognise possible benefits for the client and the organisation' that aims to provide the appropriate guidelines for benefit recognition. Next, the task 'Provide guidelines to quantify possible benefits for the client and the organisation' is executed with the aim of providing a list of possible tools and methods that can be used to quantify different kinds of benefits. These benefits are usually related to time, cost or quality. Finally, the 'Develop guidelines to exploit the benefits for both the client and the organisation' aims to provide guidelines as to how the proposed benefits can be actualised.

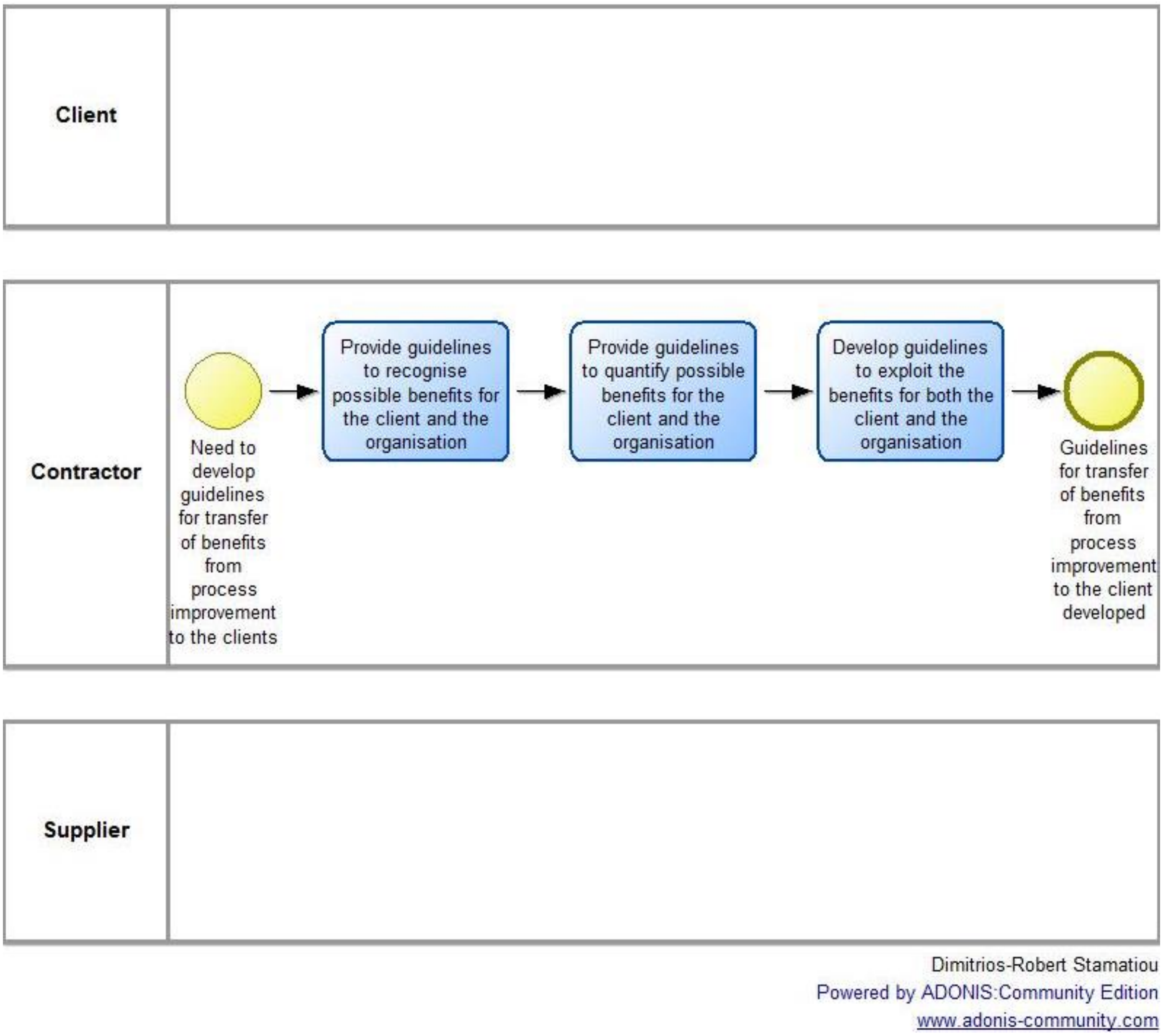

Figure 18: Develop guidelines for transfer of benefits from process improvement to the clients

The fourth strategic process is "Develop processes for client response" as seen in **Figure 20**. In order for the relationship management attempt to be successful a well-defined communications strategy and plan is required (Rowlinson 2005). Since it is impossible to foresee all potential problems in a contract, it is imperative to develop a response governance structure in order to avoid and solve any disputes that may occur during the project (Isatto and Formoso 2011). The first element of the process is the sub-process 'Develop a customer service strategy' as seen in **Figure 19**. The sub-process depicts the methodology to develop a client service strategy as described by Lambert (1992) and contains the following tasks: 'External audit', 'Internal audit', 'Evaluation of customer perceptions', and 'Identification of opportunities to gain differential advantage'.

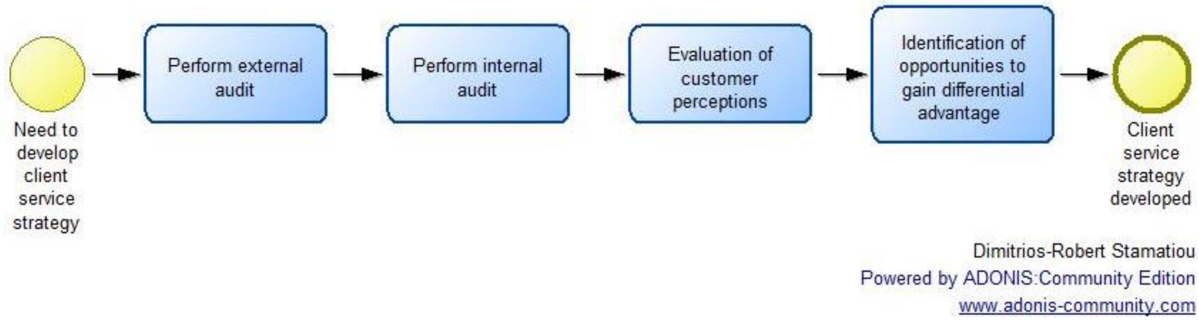

Figure 19: Develop a customer service strategy

The next task in the main process is to 'Define main events requiring response'. This will result in a list or matrix that can be used as input for the next two tasks, namely 'Determine appropriate response for each client type' and 'Determine appropriate response process for each event type'. The aim of these tasks is to describe the content and format of client service documents and processes in order to maintain a consistent service level (Nguyen et al. 2008). As Engström et al. (2009) underline, the increase of information flow to and from the client cannot always be the solution to occurring problems, especially in cases of equivocality of project parties. Finally, the 'Determine process coordination for events management' task aims at identifying the processes that are affected by the response strategies and developing a coordination framework that will allow a smooth execution of all processes during the occurrence of unforeseen events.

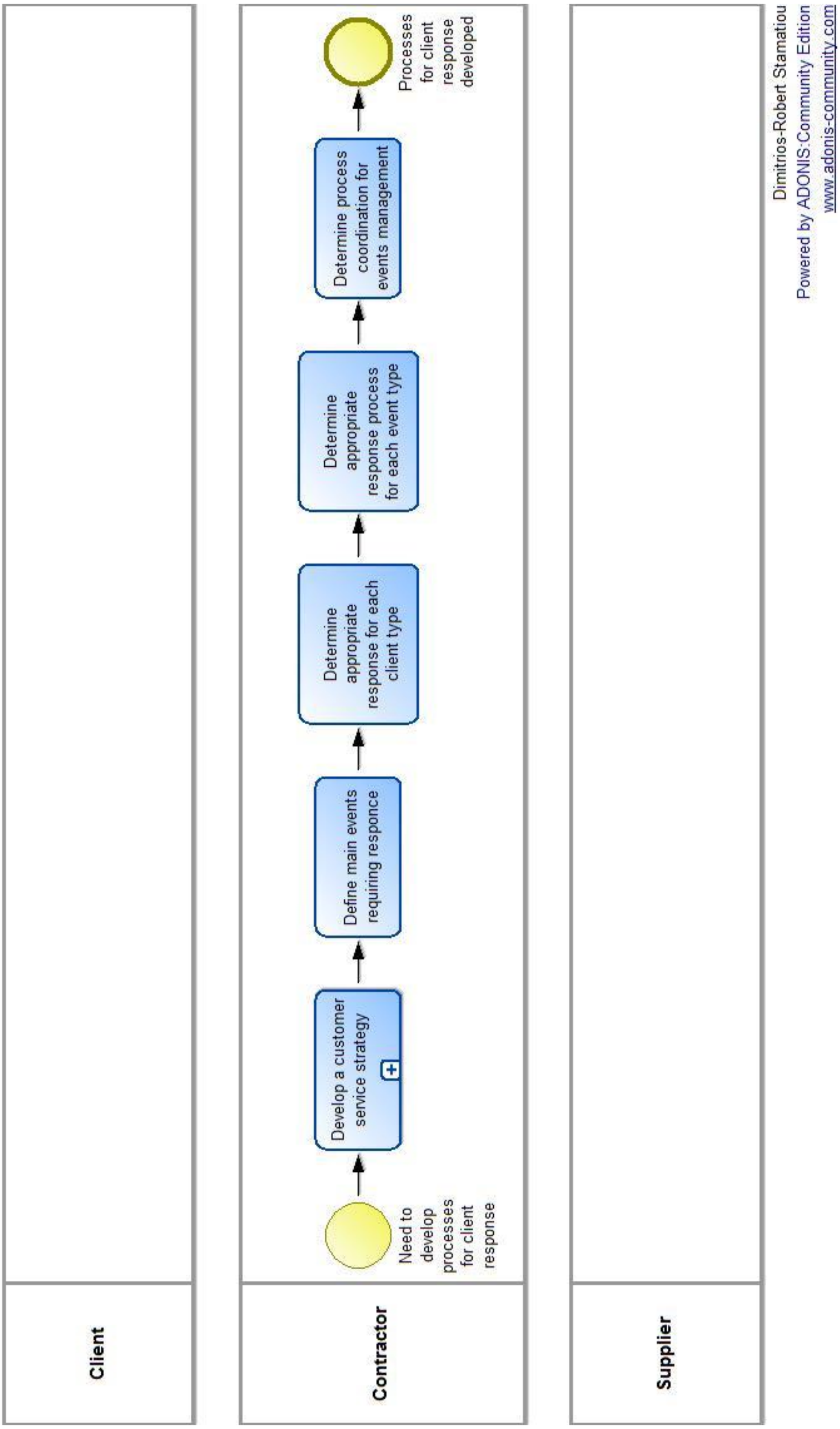

Figure 20: Develop processes for client response

The last strategic process is “Develop IT infrastructure for CRM processes” as seen in **Figure 21**. The first task is to ‘Identify sources for event data collection’. These sources could be the client, consultants, stakeholders or staff from within the company that oversee the work site. It is important to realise that there must be a differentiation of information exchange between each client in order to reduce equivocality and uncertainty and reach a level of high client satisfaction (Engström, Sardén and Stehn 2009). As Chong et al. (2013) describe, construction companies have a difficult job in collecting data from their clients due to their low frequency of transaction. The next task is to ‘Analyse business process strategy and goals’ in order to identify the correct technology that will fit with the business processes and their goals. This means that the technology must be able to deliver the right data to the right people in a way that analysis can be executed easily (Preece et al. 2015). The ‘Determine needs and constraints in information technology’ task requires the analysis of needs and constraints generated directly by the existing technological infrastructure or implicitly by other factors such as client needs or legislation. The items of interest are described by Preece et al. (2015) as: a client database; analyses of the database; tools for targeting the clients; relationship platforms; privacy issues; and critical success factors. Additionally, the firm must analyse its business processes in order to execute the next task, namely ‘Identify infrastructure to be developed’. The first step to help the staff to adopt new technologies is to show how the new technologies will assist their daily jobs. One of these technologies is BIM. The characteristics of BIM allow the tool to become a virtual information model delivered from the design team to the contractor and then to the client (Sebastian, Haak and Vos 2009). Not all clients though can or must enjoy the same access to such tools and the extent of access for each client is determined through the ‘Determine extent of BIM use per client’ task. In order to take full advantage of such a collaborative tool, Sebastian (2011) proposed the use of the “POWER” principle where the extent of “*product information sharing (P), organisational roles synergy (O), work processes coordination (W), environment for teamwork (E), and reference data consolidation (R)*” is determined.

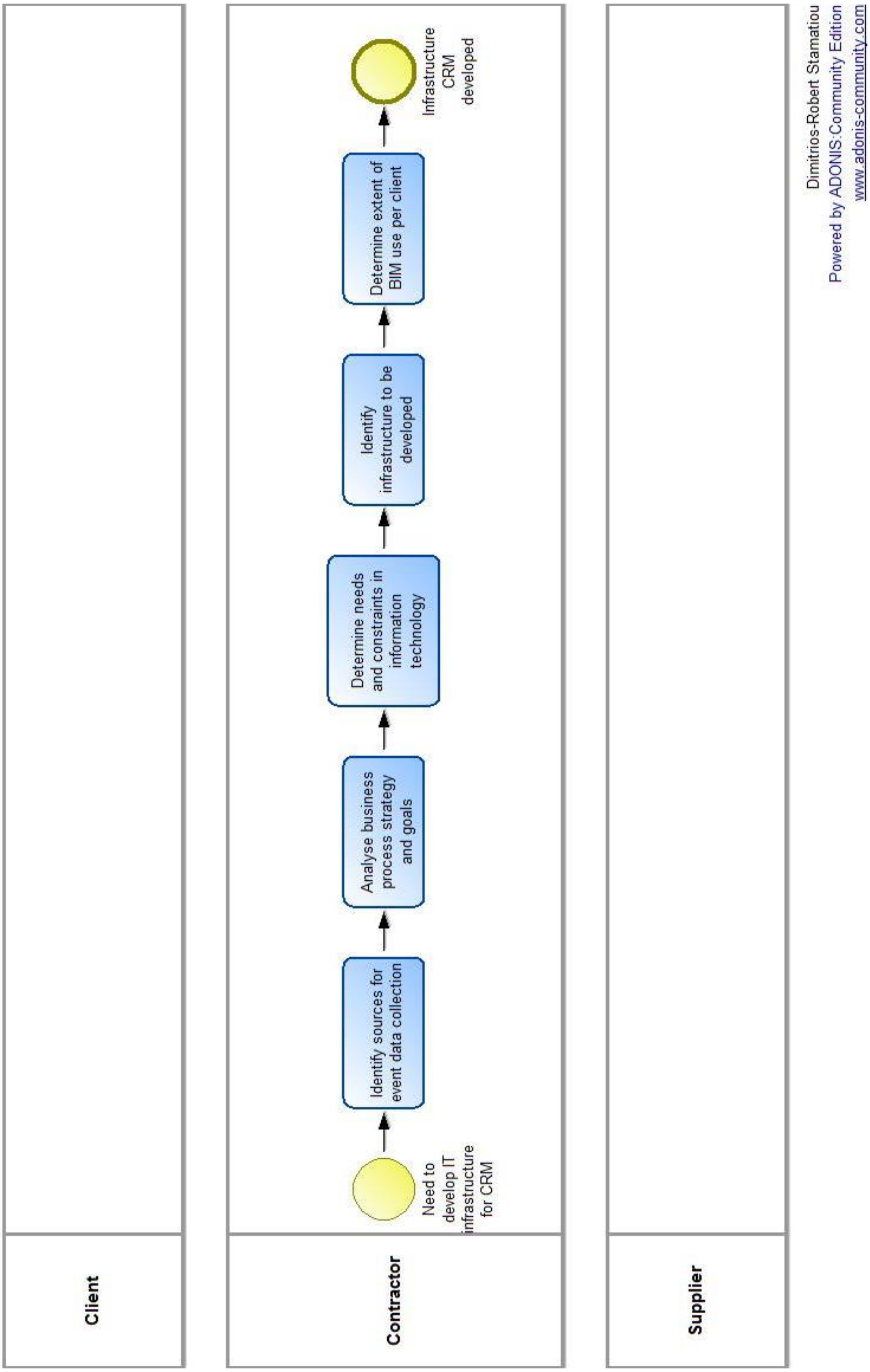

Figure 21: Develop IT infrastructure for CRM processes

4.3.2.2. Operational processes

The first operational process is “Group clients” as seen in **Figure 22**. The first task is to ‘Categorise clients based on selected criteria’ based on any of the categorisations seen in the literature (seen in the first strategic process), a combination of these categorisations or other categorisations developed within the organisation. The categorisation contains basic information such as client type (government department, local authority, statutory authority, nationalised industry, development corporation, housing association, property developer, company, other), project type (industrial, offices, commercial/retail, housing, education/training, civic, health, transport facilities) and type of management structure (Bresnen and Haslam 1991), along with more detailed information for each case such as client experience (Masterman and Gameson 1994). This allows the contractor to take the appropriate actions at each project in order to successfully fulfil the clients’ objectives (Tzortzopoulos, Kagioglou and Treadaway 2009). Next, the contractor should ‘Analyse client profitability’. Profitability is difficultly obtained in the industry, thus, not all potential clients may present value. Additionally, the ‘Evaluate potential for future work’ task adds a new dimension in the decision to make an offer for a project. Next, the ‘Group clients’ task makes use of the data produced in the previous tasks to allocate a client in a group that will make its management more efficient. Finally, the construction industry environment is extremely volatile and it is important to ‘Determine client grouping re-examination period’ in order to be able to follow any changes.

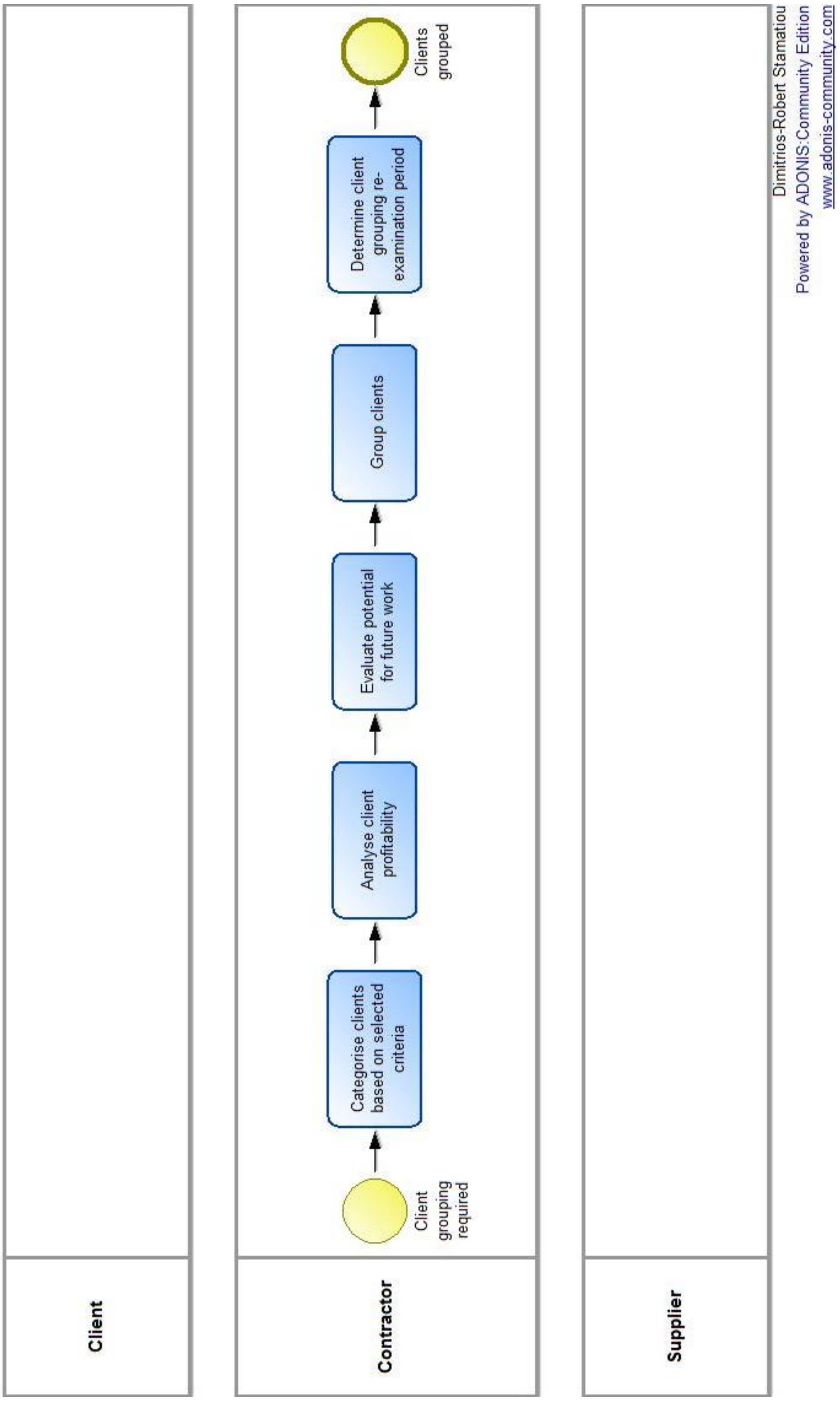

Figure 22: Group clients

The second operational process is "Prepare client account management teams" as seen in **Figure 23**. Interviews showed that this process is mainly executed by large contractors that have entire staffed departments managing clients and projects. SME contractors usually lack the funds to maintain such a construct and the head of the company is the one handling client relationships singlehandedly. For SME contractors this also depends on the type of client (public, private) and the size or requirements of the project. The first task is to 'Identify client behaviour’. Cherns and Bryant (1984) identified that there is a lack of acknowledgement of client complexity by most contractors. The analysis of the client’s organisational behaviour will allow the contractor to assess the level of risks posed by the specific client on the selected strategies (Arabiat, Edum-Fotwe and Mccaffer 2007). Next, the contractor must ‘Identify client contact’, a person or firm that will represent the client during the negotiations and, potentially, the project execution phase. Then, the contractor must ‘Select project team leader’. The project team leader is the person that will be making all the important decisions during the negotiation and execution processes and will have the responsibility of the project at hand. Next, based on the project team leader’s suggestions, the contractor must ‘Select client management team members’ that will comprise the team that manages the specific client and the strategies that are related to the client category. The National Research Council Canada (2013) describes a personnel maturity model for partnerships and CRM capabilities that can be used in order to identify the best fitting staff for the client management team. Finally, the contractor must ‘Define clients' requirements’. This is done through a detailed discussion that defines the needs and requirements of the client that constitute the clients’ attributes (Love, Irani and Edwards 2004). Best practices include requesting the client to comment on sketch designs, record minutes of meetings and to contact the predefined contact person/organisation (Dulaimi 2005). It is important to keep in mind that clients are not always aware of all their requirements beforehand and patience is suggested in the process of their identification (Cherns and Bryant 2006). In many cases there are multiple stakeholders with different agendas whose requirements have to be satisfied and this is where the contractor has to get political (Green, Fernie and Weller 2005). In this case, the contractor has to manage a state of negotiation between the clients’ requirements and business needs (Tzortzopoulos, Kagioglou and Treadaway 2009).

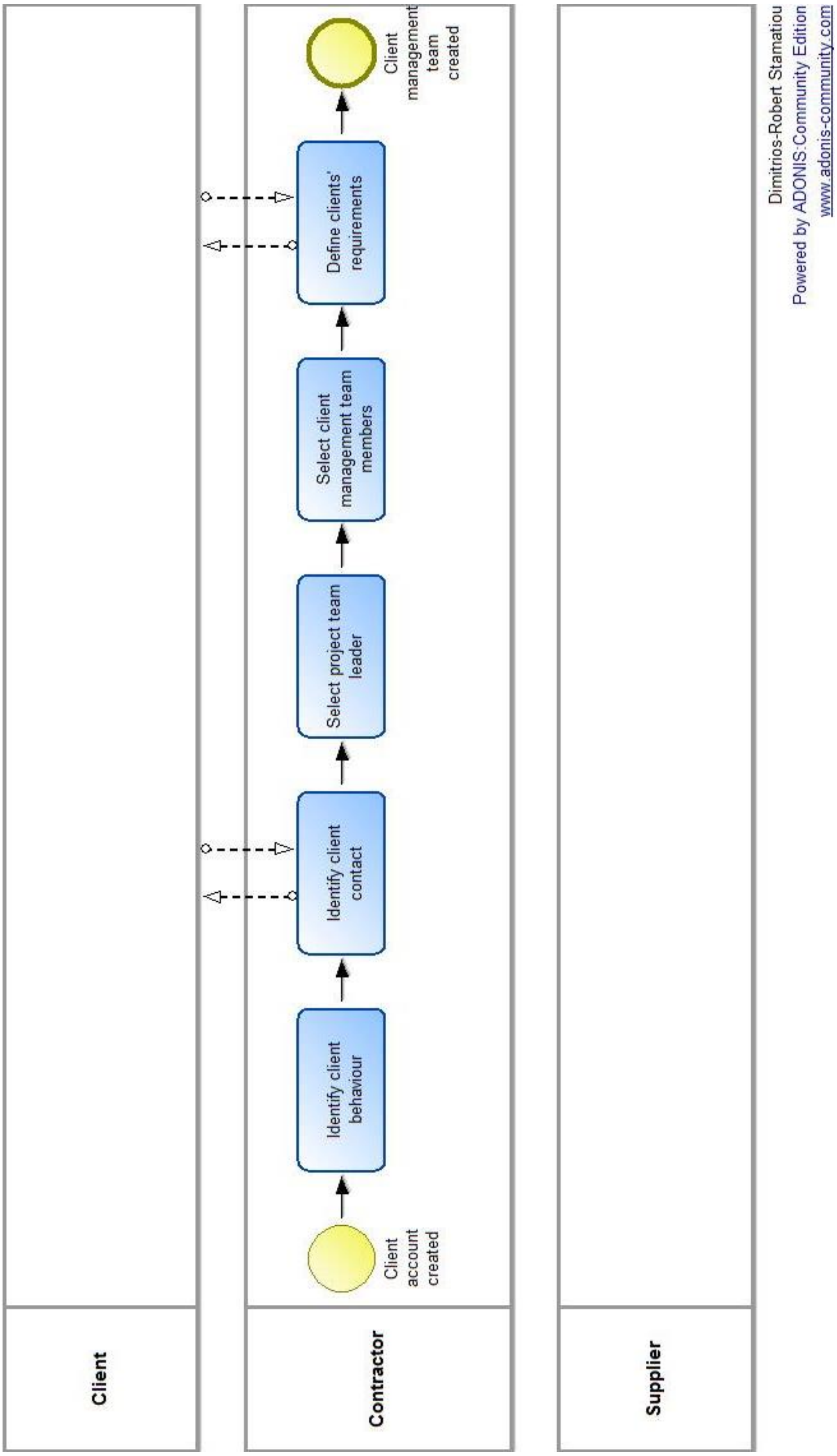

Figure 23: Prepare client account management teams

The third operational process is "Review client accounts and identify opportunities" as seen in **Figure 24**. The first task is to 'Review client history'. In the case of a recurring client, there should be a history available within the contractor organisation, in other cases suppliers or other contractors may provide a good source of information. Interviews with both SME and large contractors showed that all contractors maintain client records that, depending on the client, may extend from a simple record of designs to a record of every single email exchanged. Next, the contractor must ‘Review client size’. Usually, a smaller client has less market power than a large client but there should be an understanding of how the client size affects the project in terms of equivocality, cash flow and requirements. The information obtained in this task is used in the next task, namely ‘Analyse client’s market position’, in order to identify how work with the specific client may affect the firm’s future work possibilities in the specific market. It is important to ‘Review client’s priorities’ in cooperation with the client. This will allow the contractor to better understand the client’s needs and requirements, along with the possible tolerance to changes. Changes may be welcomed by the client if they are followed by a cost incentive. This is why the contractor must communicate with the client and ‘Identify cost reduction opportunities’. There are changes that can be identified in the design process and they solely benefit the client, but there are changes that can only be identified during the construction process and the resulting cost savings have to be shared between both parties (Rowlinson 2005). These transactions allow trust to be built. Finally, the contractor should ‘Identify service improvement opportunities’ that will make operations more efficient in future projects.

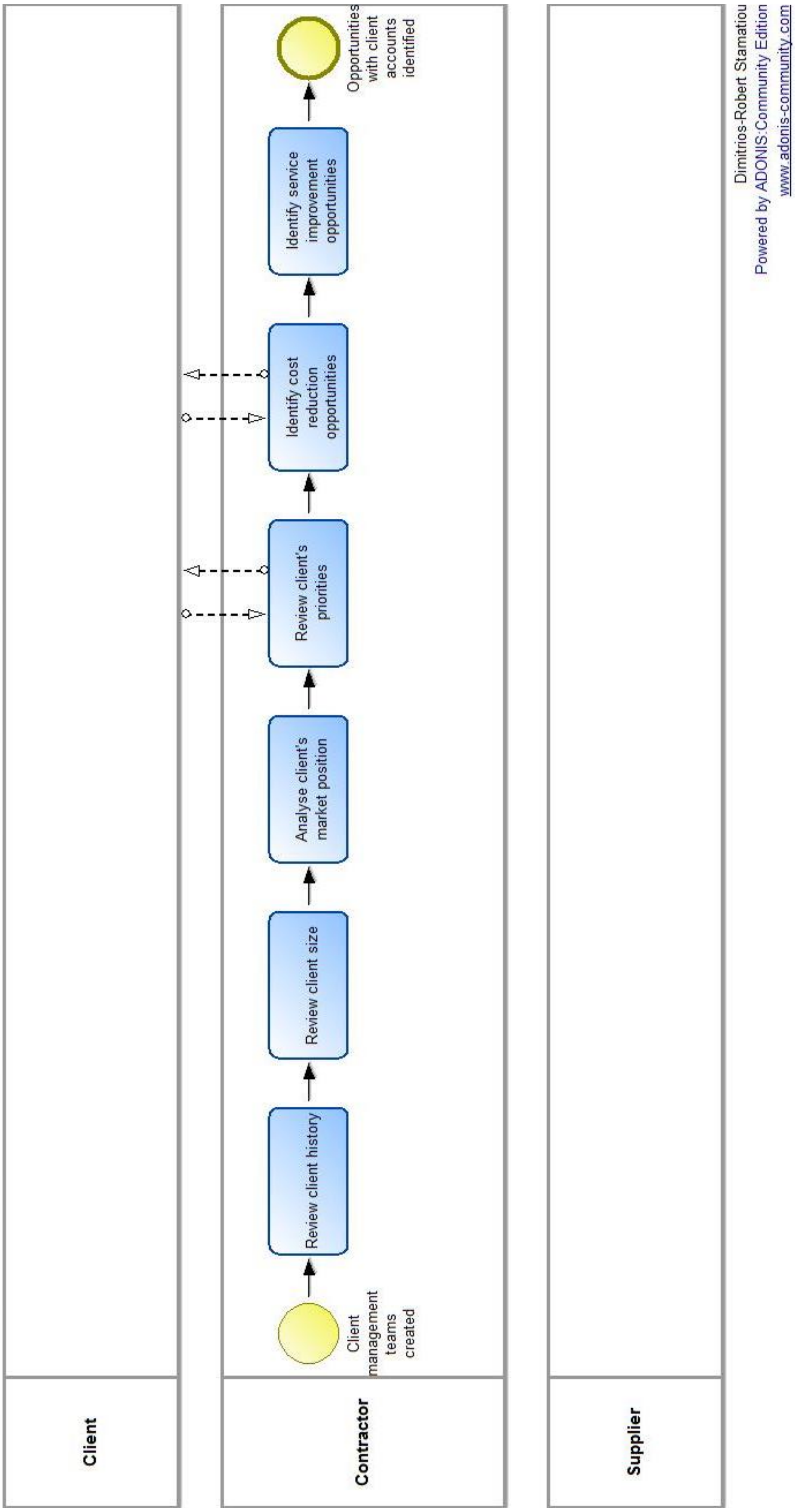

Figure 24: Review client accounts and identify opportunities

The fourth operational process is “Negotiate client project/service agreements” and, as seen in **Figure 25**, describes the contract negotiation process with the client. The first task is to ‘Prepare client contract draft’ that should contain all the clauses the contractor is not ready to give up in order for the negotiation process to go on. Next, the contractor should ‘Check client contract draft’ in order to make sure all the required fields are in place. It is important to analyse the client and determine a negotiation strategy in order to get the most out of the negotiation process, which means that it is important to ‘Determine client agreement terms’. Interviews showed that SME contractors do not always execute this specific task, in contrast to large contractors. Furthermore, it is typical for SME contractors to participate in the design stage of private clients and not require any clarifications from the client, but in cases of public clients the ‘Request clarifications’ task is always executed. Large contractors execute this specific task in the vast majority of their negotiations. The next tasks in the process are ‘Present agreement to client’ executed by the contractor, ‘Check agreement’ executed by the client and ‘Receive client’s reply’ executed by the contractor which outline the actual negotiation. The client either accepts the contract (or requests minor changes the contractor can accept) and the ‘Finalise client contract’ task is executed with involvement from both parties, or rejects the contract (or requests major changes) which means the contractor has to ‘Check set strategy for the client category’ and, depending on the client, to either ‘Withdraw client contract’ and notify the client or to ‘Develop plan to improve client contract’ and start the process from the first task.

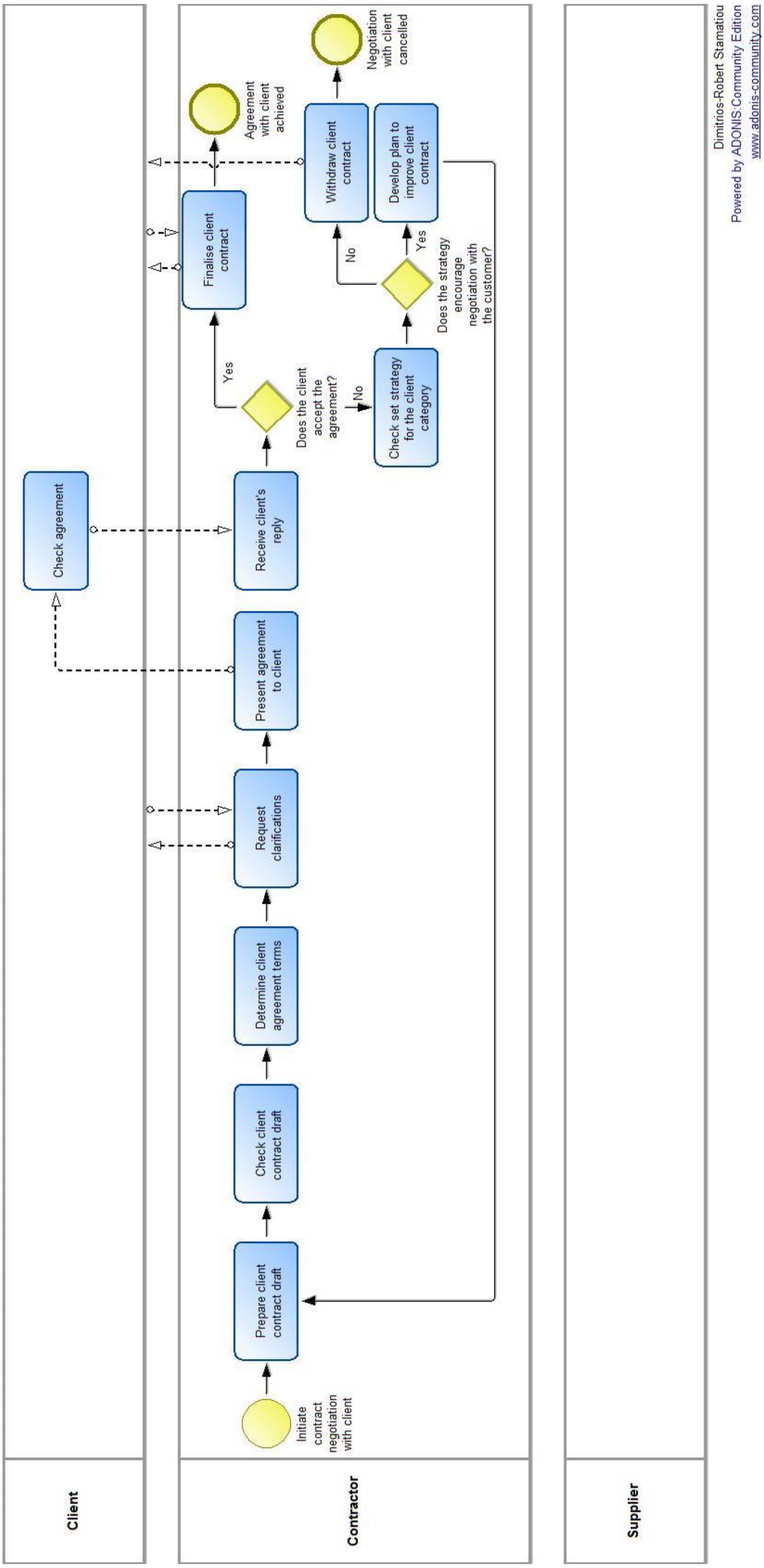

Figure 25: Negotiate client project/service agreements

The fifth operational process is "Practice client project/service agreements" as seen in **Figure 26**. After the contract has been signed, there are many problems that may occur during its execution. That is why the contractor has to 'Develop implementation plans' that will layout the strategy of communication with the client (Rowlinson 2005). The contractor must 'Provide client with access to project data' so that any discrepancies can be traced in time. "*Access involves approachability and ease of contact*" (Maloney 2002). The next task, 'Perform meetings with client', is the main method to keep in contact with the client and monitor any changes in requirements. Meetings are the best way to maintain contact with the client (Maloney 2002) and support the communications strategy in the most efficient way (Rowlinson 2005). Finally, the contractor must 'Re-examine problematic agreement areas' in cooperation with the client and, when it is deemed critical, the suppliers.

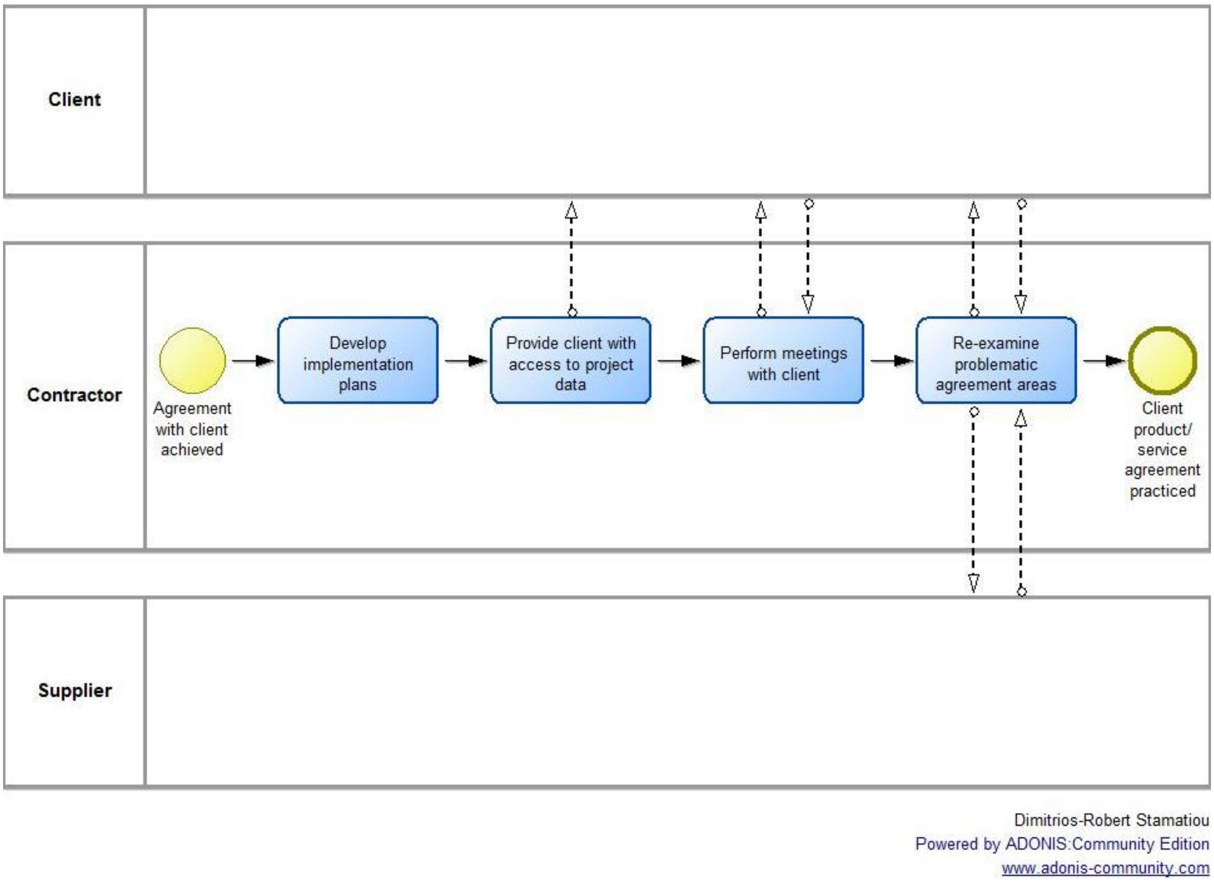

Figure 26: Practice client project/service agreements

The sixth operational process is "Event recognition" as seen in **Figure 27**. Events are foreseen or unforeseen situations that may include time, cost or quality deviations, changes that must be reported, and financial or natural phenomena that can affect the course of the project. Events are what constitute the reason for claims, but as in cooperative environments claims have to be treated differently this process describes how they are recorded before they are actually submitted. On the one hand, the client might 'Detect deviations to contract' and alert the contractor who will 'Receive event notification'. On the other hand, the contractor will 'Compare outcomes to client requirements' and, in the case that deviations are found, will 'Detect event' and report it internally. In both cases, the contractor must 'Recognise nature of event' in order to manage it as effectively as possible.

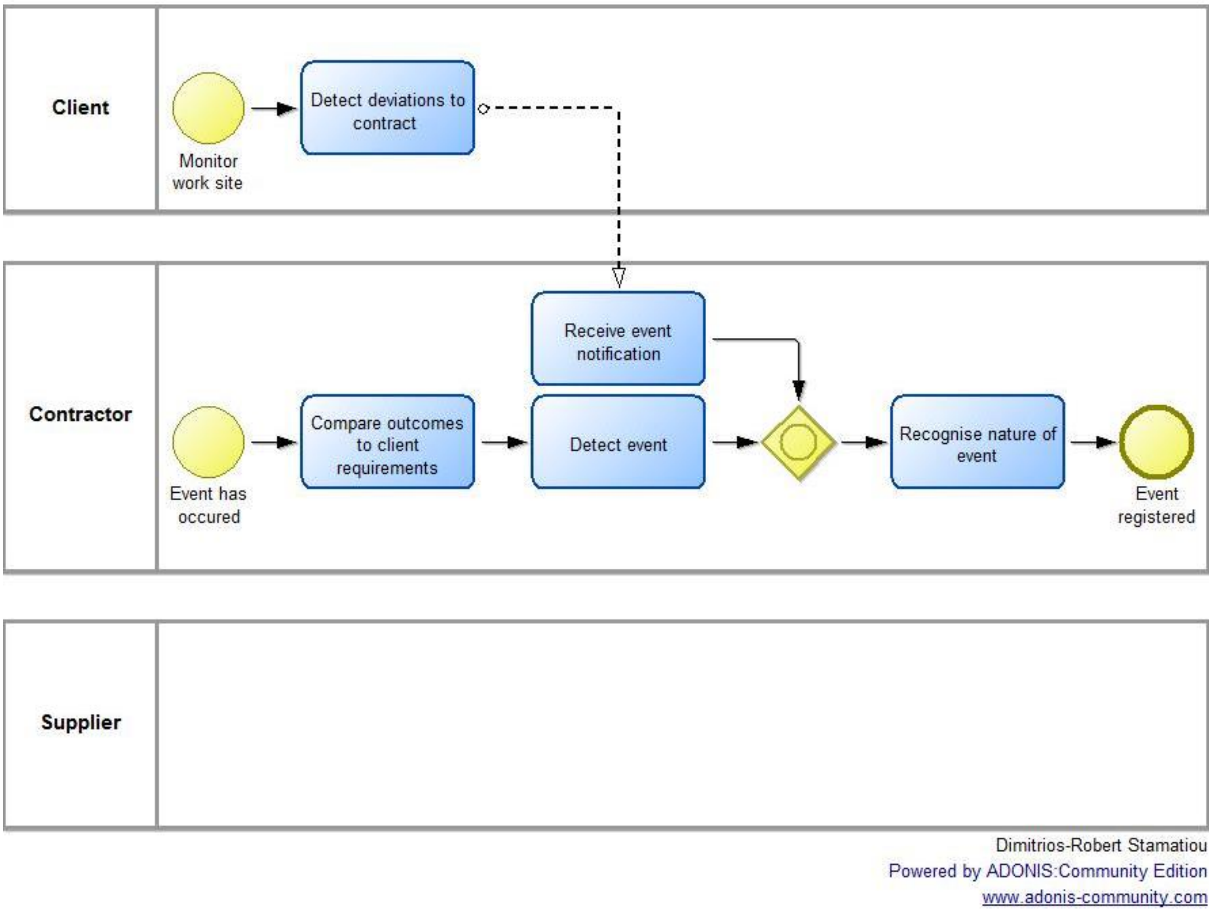

Figure 27: Event recognition

After an event has been recognised, the seventh operational process, namely "Evaluate situation and implement solution", is executed as seen in **Figure 28**. The first task is to 'Check for existing process to manage specified event'. In many cases, similar events may have occurred in a previous project which means that a solution must have already been recorded. In this case, the process ends with the implementation of the existing solution. In the case where similar problems have not been recorded in the past, the contractor has to 'Evaluate alternatives for management of specified event'. It is important to 'Estimate possible constraints during specified event management' before contacting the client in order to 'Determine solution process steps'. It is important to remember that suppliers might provide valuable input to the aforementioned task. Finally, if a solution has been agreed upon, the contractor must 'Implement solution. In other cases, the client or contractor might move forward with a claim. This is the content of the 'Submit/receive claim' task. Claims management is described in section 4.10.

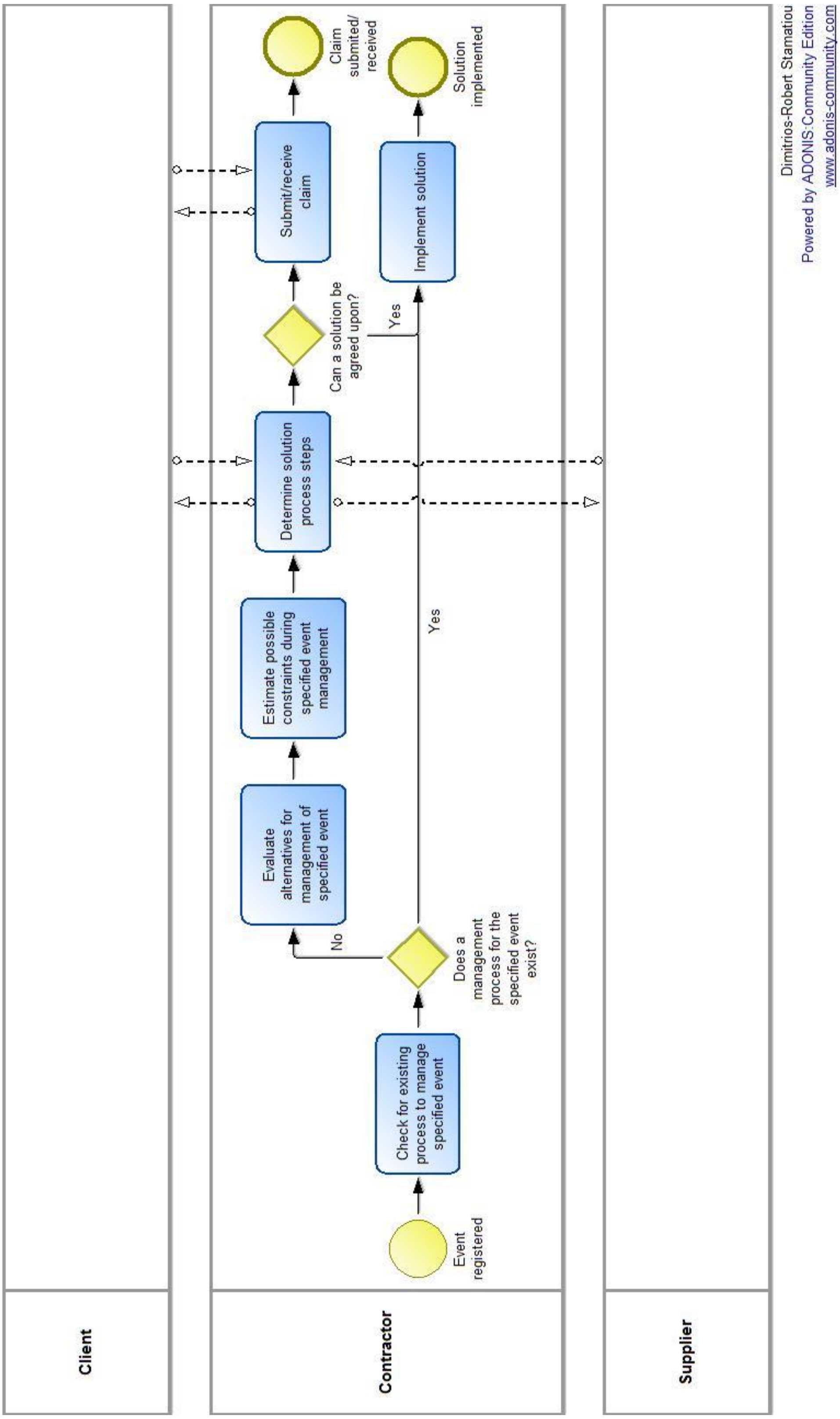

Figure 28: Evaluate situation and implement solution

The eighth operational process is "Evaluate client satisfaction" as seen in **Figure 29**. The contractor should first 'Select client satisfaction measurement method'. Gunning (2000) identified four models of client satisfaction measurement in the concurrent literature, namely the Disconfirmation of Expectation Model, the Performance Model, the Rational Expectations

Model, and the Expectations Artefact Model. These models have different characteristics and the selection of the most fitting one should be made after their careful study. In the case of trilateral relationships, the 'Multidimensional Model of Client Success When Engaging External Consultants' evaluation model developed by Gable (1996) has been deemed as the most appropriate choice for satisfaction measurement (Gunning 2000). Next, the contractor should contact the client and 'Request client evaluation' based on the selected tool. It is important to keep in mind that client expectations "*play an extremely important role in the evaluation of performance*" (Maloney 2002). The input from the client is used for the 'Compare client relationship management results to client expectations' task. The contractor has to keep in mind that client satisfaction is dependent on many parameters, one of which is the degree of control and supervision by the client itself (Walker 2015). Communication plays an important factor for client satisfaction as well (Nguyen et al. 2008). Especially in cases of relational contracting, team-working, relational attitudes, capability, team integration, joint working, and contracting play important roles in client satisfaction (Suprapto et al. 2015). Finally, the contractor has to 'Identify methods of client satisfaction improvement'. Factors that may be reconsidered during satisfaction improvement are: monitoring perceptions of client satisfaction, identifying areas of satisfaction shortfalls, taking appropriate action, requirements identification, requirement analysis and prioritisation, and requirement translation (Gunning 2000). Nguyen et al. (2008) proposed the following methods to improve client satisfaction: conducting employee trainings, treating employees as satisfied clients, and conducting client satisfaction surveys.

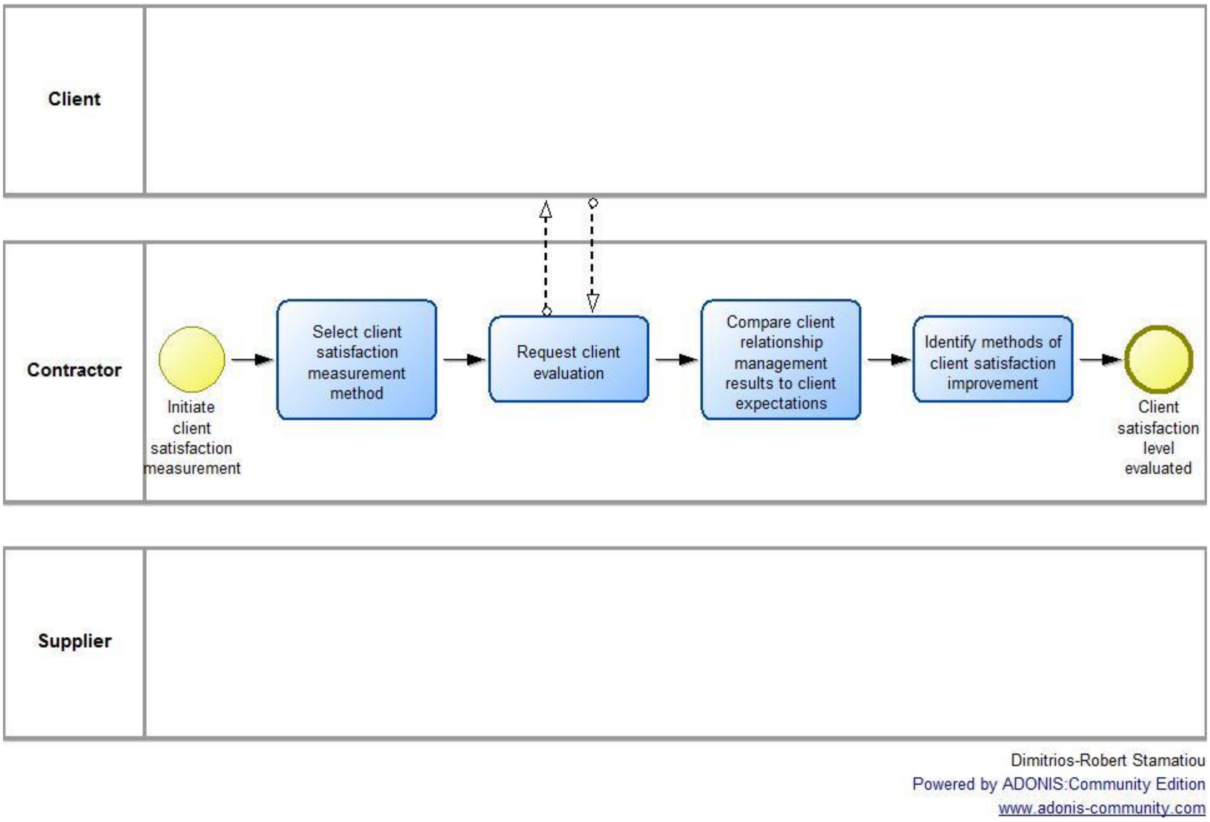

Figure 29: Evaluate client satisfaction

As Sear et al. (2008) argue, client relationship management implementation "*requires clearly defined measures in place; key performance indicators and key performance outcomes will help structure the measurement of success*". This is the content of the last operational process, namely “Client relationship management performance measurement”, as seen in **Figure 30**. It can be executed for either previous operational process independently or for all of them collectively. The first task is to ‘Record and classify client relationship management process data’ and aims at monitoring process execution and collecting the relative data generated. Data is generated during both the execution and the result of each process and underperforming or overachieving operations can be recognised through this task. The following task, ‘Monitor client relationship management performance indicators’ uses the data collected previously to compare with the performance indicators set at the strategic level. Next, the ‘Detect main problems in client relationship management’ task aims at identifying the major problems that occur in the client relationship management processes for each individual client and client group. The contractor should ‘Draft client cost and profitability reports’ for each individual client and client groups based on the financial indicators recorded and aims at identifying the costs and the profitability that have been incurred by the execution of the entire client relationship management function and the clientele in total. In addition, the contractor should ‘Record events in database’ in the case of an existing database or should create a database in the case there is not one in function. Finally, the ‘Determine performance improvement objectives’ task is executed. The task aims to capitalise the acquired knowledge for improving performance in future projects. These objectives can be shared with other key parties of the supply chain. As Engström et al. (2009) argue, contractors working with industrial clients in specific can become more competitive if the contractor supports the client’s learning process.

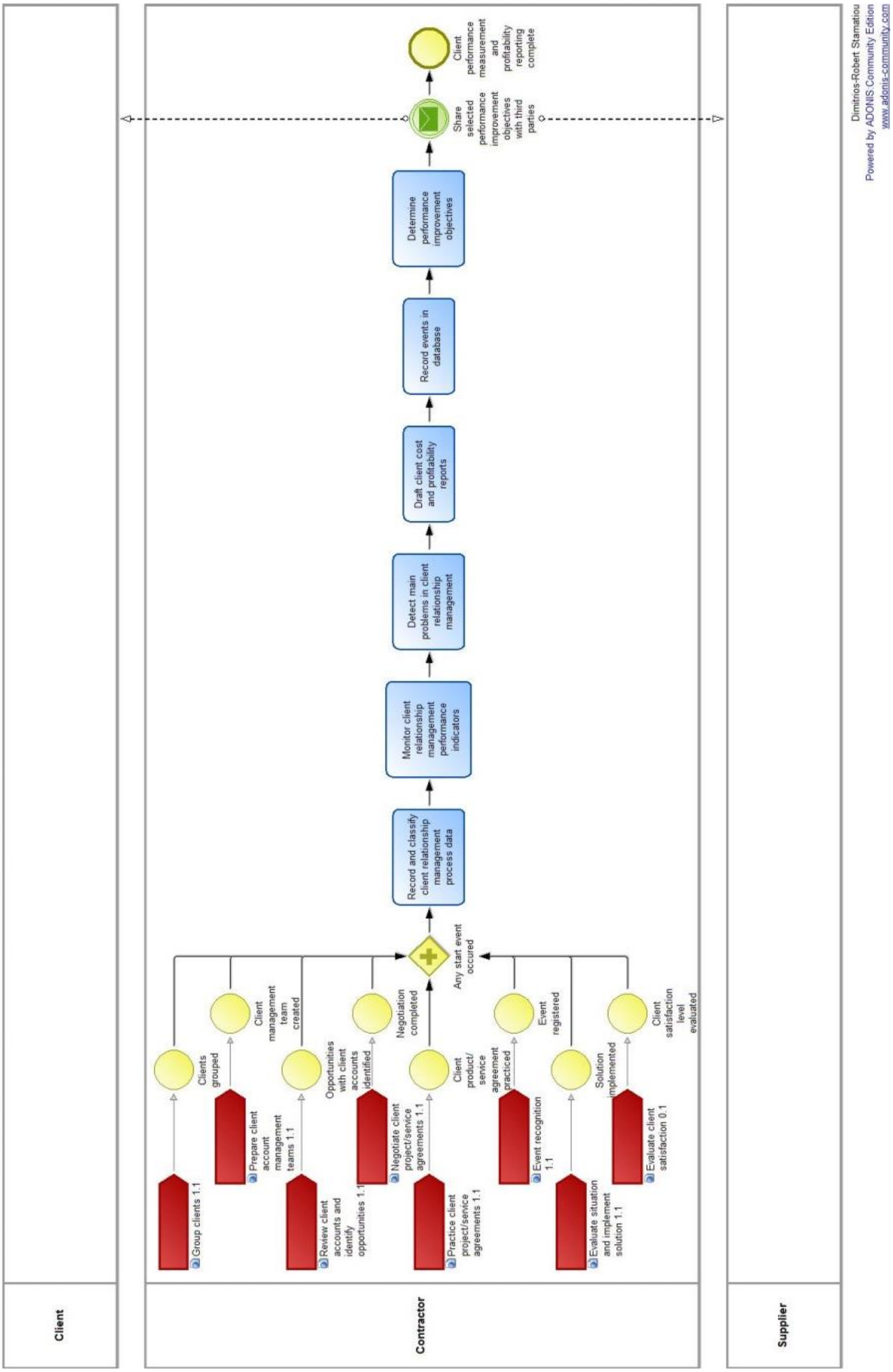

Figure 30: Client relationship management performance measurement

4.4. Project development and commercialisation

4.4.1. Analysis of project development and commercialisation

Every project that has been, is being and will be implemented goes through a rigorous and demanding design phase. The design phase aims at fulfilling the clients' needs and to provide all required information for correct implementation to the subcontracting parties. The evolution of a building over its lifecycle involves many stages starting from design and ending at demolition and each stage requires the collaboration of many actors (Bouchlaghem, Kimmance and Anumba 2004). The design phase is the most important contributor to the performance of a project since mistakes in design lead to project delay, poor performance, and budget overrun (Yusof, An and Barghi 2015). Bouchlaghem et al. (2004) identified that "*the modelling of processes necessary to generate the product are largely ignored*". Depending on an actor's role in the development of a project he may have an increased or limited contribution to requirements specification, new approaches suggestions, constraining, stimulating, and negotiating compromises that affect design and development (Brandon 2011). In manufacturing, product development and commercialisation is the process that provides the structure for collaborative development and marketing of new products or services along with customers and suppliers (Rogers, Lambert and Knemeyer 2004). Additionally, relationship quality, knowledge transfer, and new product development performance have been positively correlated with the involvement of both suppliers and customers (Sjoerdsma and van Weele 2015). This, results in new product development (NPD) processes often being decentralised across the supply chain (Yoo, Shin and Park 2015). In the case of the construction product (a new construction project) the process is equally important but more complex. Each party may only be involved in a single or a few work packages of an entire project. Work structuring refers to the design of the project organisation and according to Ballard (1999) it includes: how work is divided into work packages, how work packages are assigned to different project participants who perform the work, and how production steps are sequenced. Work structuring affects both coordination and production costs in a project (Tsao et al. 2004). The coordination of all the requirements and constraints posed by each party has to be impeccable during the design phase in order for the construction phase to roll smoothly. The following should be considered in work structuring according to Mitropoulos and Sanchez (2016): owner budget pressures, owner requirements, skill and certification requirements, economies of scale, bid package attractiveness, coordination considerations, liability considerations, and transaction costs.

Once project design processes have been completed, along with a thorough check for problems, the final input to the project plans should contain no mistakes. It is important to define the design process in order to set the expectations of design users. Lyon ((2005) as seen in Lyon (2011)) defines design as follows: "*Design is a cognitive process that consists of the consensual production of meaningful artifacts through a knowledge capture, generation, manipulation, synthesis and communication process*". It is more of a "*negotiation process between multiple actors and several related aspects flowing together along time*" (Lyon 2011). Lahdenperä and Tanhuanpää (2000) highlight that the design process involves information exchange between numerous designers that has to be coordinated by a single person who understands and provides input to all design disciplines. The design process aims to narrow down the tuple of options that attempt to meet the client's requirements to a single one, thus reducing uncertainty over the design (Winch 2001).

In construction each new project is a prototype that cannot be replicated. This makes the design phase of a project an integral part its production. Despite this, Brandon (2011) noticed that the design process is seen as something separate from the construction process. Design is not a simple process, it must take many aspects such as legal, financial, spatial, functional, and structural into consideration (Lyon 2011). Additionally, design is not a one-step task, it progresses from concept development, through detailed design and component selection to the final detailed design (van Donselaar, Rock Kopczak and Wouters 2001). Liu and Zeng (2009) highlight that up to 80% of the cost is committed by the end of the design phase. The term design chain is used to describe the actors and their transactions during the design phase and is a subset of the supply chain but its management is more difficult than that of the supply chain (Shiau and Wee 2008). The fact that there is no commonly accepted good practice for the design phase in cohort with the demand for fast track delivery make it very hard to coordinate all the parties related to the project (Bibby 2003). Bankvall et al. (2010) analysed and extended Thompson's (1967 as seen in Bankvall et al. 2010) work into the construction industry and presented four types of interdependencies in construction projects: pooled, sequential, reciprocal, and synchronic interdependencies based on the relationship of the project's tasks. These interdependencies have become more important during the last decades when the number of specialisations increased and new technologies lead to reductionism at the task level and fragmentation in the supply chain (Brandon 2011). In this setting, the role of the architect, in specific, has become more complex and he is expected to verify satisfactory performance of project parties, facilitate negotiations, and provide a first line of dispute resolution during both design and construction (Winch 2001). It is also during the design phase that the level of modular construction use is determined. The selection of modular construction must be agreed upon by designers, engineers and contractors after the following factors listed by Azhar et al. (2013) have been examined: suitability of design for modularisation; use of repetitive components in the design; structural stability of individual and assembled modules; organisation's familiarity with modularisation; owner's receptivity and willingness to accept modular construction; need for expediting the schedule; early upfront involvement of top management in the project; well defined project scope and budget; integration of a well-versed team and strong collaboration among players; getting complete product submittals, shop drawings, and co-ordination drawings ahead of decision-making; competitive edge on bidding; and site accessibility.

It is through the project development and commercialisation process that work packages are defined. Work packages are defined through the work structuring process which "*determines the scope of each work package, and the dependencies between work packages*" (Mitropoulos and Sanchez 2016). Traditionally, work packages contain information about their cost and duration but it is common practice not to include the uncertainties that bound such estimations (Boskers and AbouRizk 2005). In addition to the exclusion of uncertainties, problems during project execution arise due to poor scheduling during this phase (Boskers and AbouRizk 2005). According to Ibrahim et al. (2009) the contractors consider the following decomposition criteria for work packages: work section, elements, facility, construction aids, construction product, attributes, management, spaces, function location, and lifecycle phases. Contractors, according to Mitropoulos and Sanchez (2016), must develop effective work packages that take into consideration local practices, availability of suppliers, and avoid double mark-ups by contacting second tier suppliers. Work structuring "*determines the need for coordination between the project participants*" (Mitropoulos and

Sanchez 2016). Studies have shown that early involvement of key suppliers can prove beneficial for work structuring (Gardner 2006, Ponticelli, O'Brien and Leite 2015, Alleman et al. 2017). As it is proposed with manufacturing products (Rogers, Lambert and Knemeyer 2004), Alleman et al. (2017) proposed that the early inclusion of key project participants can provide benefits for the project through the following: procurement of long-lead items, price sensitive items, or both; concurrent design and construction; early work performance (e.g. right-of-way, utility, subsurface, or preparation work); and avoidance of environmental restrictions or disadvantageous seasons. Not all work packages have the same significance on the project. Usually, 20% of the work packages bear 80% of the project cost. Horner and Zakieh (1996) introduced the term `Quantity significant work packages' that described work packages consisting of groups of items that omitted quantity insignificant items. Research performed by Mitropoulos and Sanchez (2016) identified two sets of conflicting considerations affecting work structuring: acquiring the project appointment, and performing well during the construction phase. But these considerations do not always belong to one party. Work structuring may be exclusively the project owner's consideration, exclusively the general contractor's consideration or may involve a debate between the project owner, the general contractor and other parties. In the case of the project owner, there is preference for many small work packages that drive bids lower whereas, in the case of the bidding parties, larger packages are preferred due to the opportunity to take advantage of 'economies of scale' or 'economies of coordination' (Mitropoulos and Sanchez 2016). Both approaches have advantages and disadvantages for each party and this creates a need for trust and collaborative work during project design.

The project design and development phase has a few problems related to its processes, some of the main being fragmentation of design and no downstream information flows (Anumba and Evbuomwan 1997). The lack of coordination in design leads to unnecessary prolongation of the phase due to redesign requirements and flawed solutions (Lakka and Nykänen 1992). Designers usually delay communication of demand information, even if they have acquired such information, to contractors in order to minimise the effects to their business caused by the risk of changes (van Donselaar, Rock Kopczak and Wouters 2001). Some of the factors contributing to design errors are designers' lack of construction knowledge or experience, lack of time to prepare a high-quality design documentation, working on two-dimensional documentation which hinders design verification, lack of coordination between subjects, wrongly defined or imprecise scope of duties, and human errors (Juszczyk et al. 2014). There are many factors of bad design practice that lead to waste during both the design and construction phase, such as the following listed by Yusof et al. (2015): poor client briefing, inadequate pre-design project meetings, lack of project definition, design defects, inadequate technical knowledge, poor specification, design changes, insufficient and unrealistic constraints of project cost, insufficient and unrealistic constraints of project time, inadequate involvement of other professionals and teamwork during the design stage, lack of constructability review of design, poor communication among design team, making design decisions on cost and not value of work, poor level of commitment to quality improvement among design professionals, and effect of design code and standards on quality. The effects of such waste can also be seen in the increased cost during the construction phase (Lahdenperä and Tanhuanpää 2000). The inclusion of other parties in the design phase can provide designers with information that could lead to the avoidance of such problems. Two fundamental barriers to the inclusion of other parties in design are geographical separation and corporate culture incompatibility (Rogers, Lambert and Knemeyer 2004).

In the manufacturing industry, collaborative new product development has become more popular due to increasing competition and market globalisation (Liu and Zeng 2009). Likewise for the construction industry, Shelbourn et al. (2007) consider collaborative working essential for design and construction teams in order to cover the entire lifecycle of the construction process. The final construction product is an extremely complex and sophisticated product that requires many sophisticated technologies. Just as Yoo et al. (2015) identified for a manufacturing product with such characteristics, "*it is inefficient and virtually impossible to command all the relevant technologies necessary to satisfy customers' needs*" without collaborating with the suppliers. Collaboration is not a panacea to be applied for all problems related to new project design, it must be conducted wisely since there are cases reported in the literature, for example Primo and Amundson (2002), where ordinary suppliers helped improve the product quality but critical suppliers impeded the progress of projects. In the same wavelength, Ferreira (2011) reported that considerable gains were obtained from integrating the project development process, but problems related to the remote collaboration and coordination of different parties emerged. In many cases, collaborating parties simply rely on information technologies alone for collaboration, but Shelbourn et al. (2007) highlight that this practice is not enough and a number of other factors related to vision, stakeholder engagement, trust, communication, processes, and technologies must be examined before collaboration takes place. Simonin (1997) supports the notion that experience with past partners affects the approach of each company to collaboration. Successful collaboration is highly dependent on both organisational maturity (Shelbourn et al. 2007) and individual behaviour (Lu, Zhang and Rowlinson 2013).

Mazzola et al. (2015) investigated the operations and supply chain management literature and identified a large amount of work related to customer and supplier involvement in new product development. In construction, it is also essential to exchange information and communicate with other actors of the supply chain (Love, Irani and Edwards 2004). In design and development specifically, supplier involvement is a major part of the process (Croom 2001). Although suppliers present a source of innovation, it is hard to unleash their potential (Sjoerdsma and van Weele 2015). Sjoerdsma and van Weele (2015) examined the contemporary literature and identified fourteen independent factors affecting new project development with the involvement of other supply chain parties: access to resources and knowledge; information sharing; efficiency and effectiveness in New Project Development (NPD) processes; organisational performance; value through synergy; innovativeness; NPD complexity; customer satisfaction; profit margins; supplier contribution of new ideas; quality of relationship; joint problem-solving activities; manufacturability of the product; redesign and rework. A method that allows the project owner to maintain control over both design and construction is the CM-GC (Construction Manager – General Contractor) method that involves the owner contracting with a construction manager for project design who later becomes the general contractor for construction (Alleman et al. 2017). This method is used when risk is mitigated upstream the supply chain by the owner but allows the general contractor to have expert knowledge of the project design early on.

One of the most promising principles, that of concurrent engineering (CE), is believed to hold many solutions for the improvement of construction industry competitiveness (Bouchlaghem, Kimmance and Anumba 2004). In order to reap such benefits, Anumba et al. (1998) support that integrated product and process information systems must be developed among other things. Bouchlaghem et al. (2004) recorded instances in the literature of organisations implementing business process management solutions through ERP software that could not always be characterised as successful. It is true that ERP systems have been developed for the manufacturing industry and their application to the construction industry requires great parameterisation that may lead to underperformance. Shelbourn et al. (2007) described the specifications of such software as covering the following: general terms (enabling the exchange of information and communication between stakeholders), design (enabling the exchange of design ideas and iterations, versioning, and real-time monitoring), construction project management (enabling access to most up to date project information and progress monitoring to all stakeholders), visualisation (enabling view of complicated information sets in a recognisable format for all stakeholders, which leads to easier change management and conflict resolution), and simulation (enabling stakeholders to experience building use before onsite activities begin). Such a software platform is BIM (Building Information Modelling) that provides efficient and effective utilities in project delivery and a way to cope with cooperation integration and coordination challenges (Lu, Zhang and Rowlinson 2013). There are few BIM platforms available in the software market, but they require an investment in both monetary terms and personnel training. There are also tools developed by academics available in the literature that focus on specific parts of the design process, such as the 'Sistema π' developed by Ferreira (2011) that focuses on knowledge distribution and decision support in design. Azhar et al. (2013) believe that the extended use of BIM will provide a vehicle for increased future applications of modularisation because of the increasing demand for green projects and increased productivity. Despite the advances in the BIM platforms, the most important parameter for successful design and construction is, and will be, human intervention and dialogue (Brandon 2011).

4.4.2. Project development and commercialisation process model

The "Project development and commercialisation" (**Figure 31**) function is the third management function in the model and includes the processes related to the analysis, selection and development of new projects. It is comprised of nine processes; four strategic and five operational. Projects can be seen as a new product in a manufacturing point of view, thus, as Rogers et al. (2004) underline, "*it is critical to have the right people from the internal functions along with key customers and suppliers involved in the product development and commercialisation process*". The strategic processes are the following four and can be executed whenever required and with no specific order: "Develop idea generation and examination process", "Develop guidelines for project development personnel selection", "Identify problems and constraints for new project initiation", and "Develop guidelines for new project development". These processes provide the guidelines for new project development operational processes. There are five operational processes in the model: "Define new projects and assess suitability", "Formation of project development team", "Formalise new project development", "Evaluate construct/subcontract decision", and "Project development and commercialisation performance measurement". The first four operational processes are executed sequentially, but the fifth one can be executed either in sequence to all or in parallel to each of the other operational processes. Commercialisation in the construction industry is based on the type of contract that will be signed with the customer. The options range from design-bid-build to very complex arrangements such as those seen in **Table 2**. Contracts and arrangements are examined in the "Customer relationship management" and "Supplier relationship management" functions, thus there is no analysis of commercialisation in the processes presented in this section.

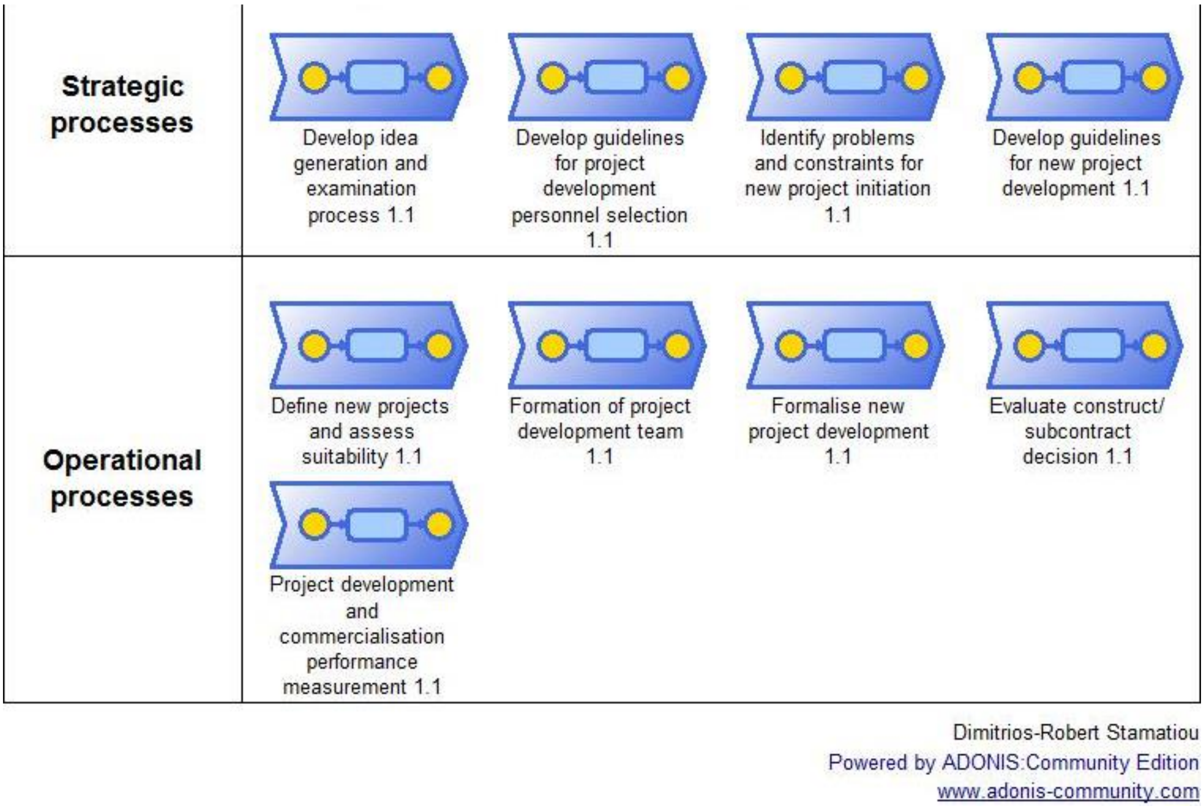

Figure 31: Project development and commercialisation

4.4.2.1. Strategic processes

The first strategic process is "Develop idea generation and examination process" (**Figure 32**) and aims to create the guidelines that will be followed for each new project idea generated and examined. The first task is to 'Determine sources of new projects'. New projects could originate either from within the construction company or by another organisation that will participate as the client. The client may present a new project that has already been designed and require solely the construction part or require that the contractor company participate in the design process either as the designer or collaborate with the designer. In some cases, the contractor may be notified by key suppliers about forthcoming tendering events. Next, the task 'Establish incentives for new projects' is intended to set some guidelines for when new projects can/or must be picked up. The third task, 'Create standardised client feedback system', aims to create an interface for communication with new clients about the new projects being examined. Finally, the 'Establish guidelines for new project strategic fit evaluation' aims to procure the operational phase with a shortlist of tasks to be performed in order to examine the strategic fit of the project under examination. This shortlist contains, without being limited to, the analysis of the project work breakdown structure (WBS), organisation breakdown structure (OBS), risk, and project breakdown structure (PBS) (Dey, Tabucanon and Ogunlana 1996).

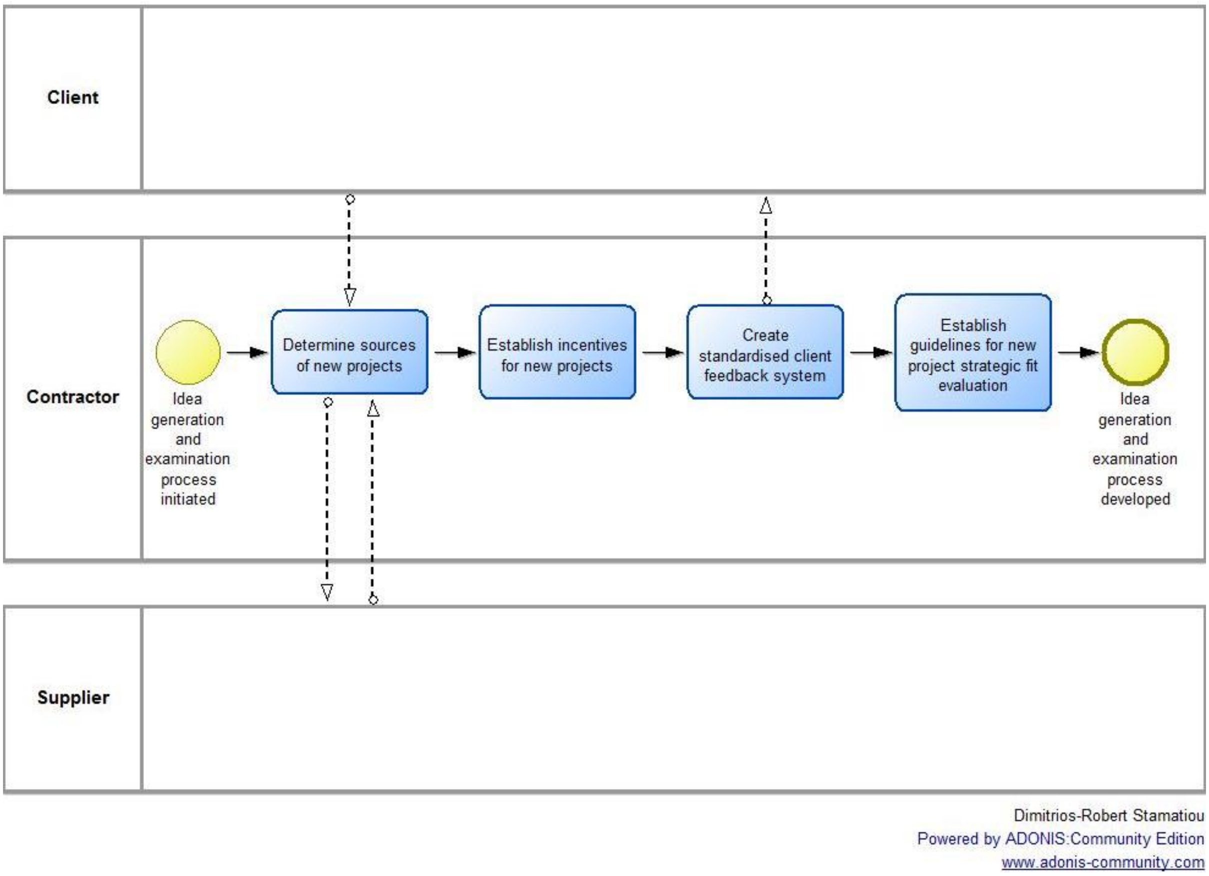

Figure 32: Develop idea generation and examination process

The second strategic process is "Develop guidelines for project development personnel selection" (**Figure 33**) and aims to provide a set of guidelines for personnel selection in project development tasks. The first task is to 'Determine level of client and supplier involvement in project development'. The involvement of other parties in the project development process requires that certain personnel will be employed in the communication and information exchange with such parties which, if the case, may lead to additional personnel requirements. Next, the task 'Evaluate availability of skills in current personnel and need for training in new skills' aims to identify any lack in skills needed by the current company personnel for the new project. If any shortcomings are identified, there are two options to examine based on available resources: training and recruitment. Finally, the task 'Examine constraints in resources' is intended to identify any other constraints posed by resources upon new project development personnel.

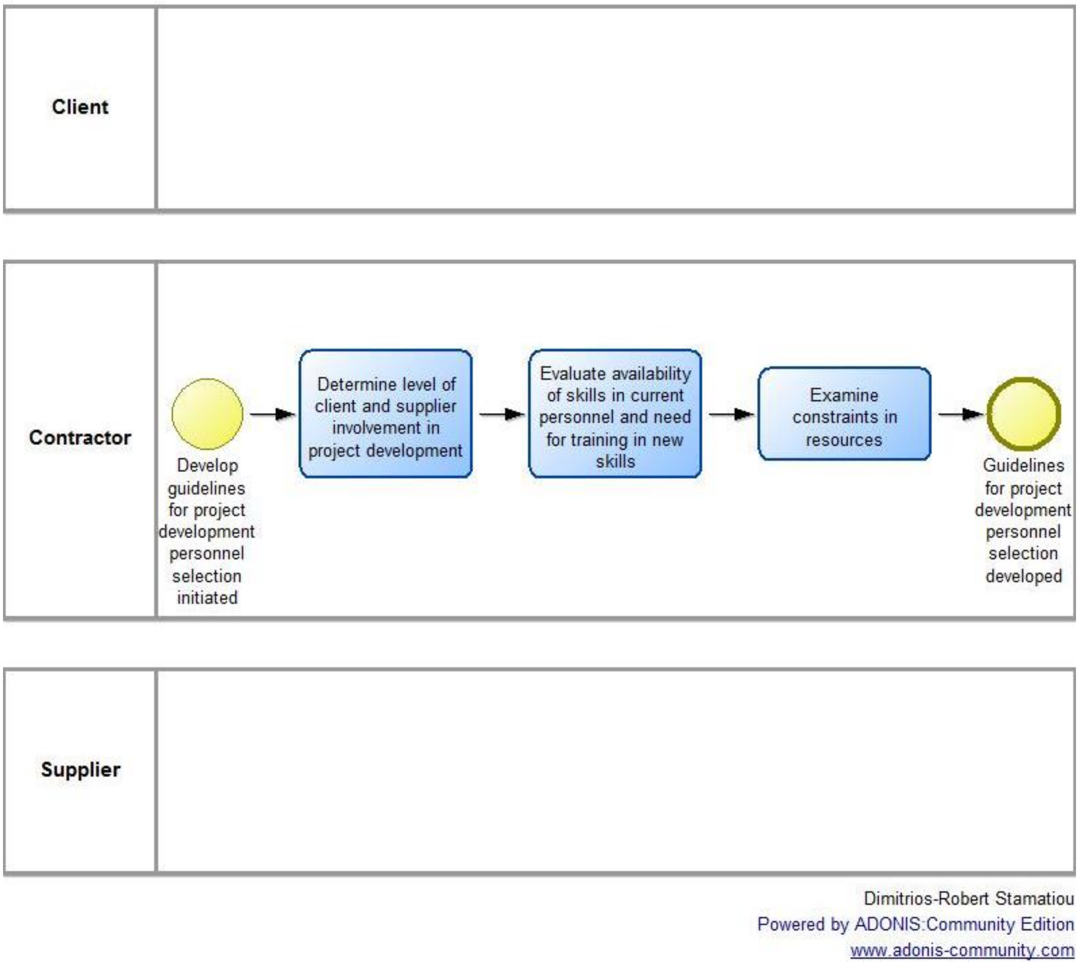

Figure 33: Develop guidelines for project development personnel selection

The third strategic process is "Identify problems and constraints for new project initiation" (**Figure 34**) and aims to identify any potential problems and constraints related to the initiation of the new project. The first task is to 'Examine potential project pinch points'. Pinch points are tasks in processes where congestion is likely to occur and hamper the execution of the project as scheduled or designed. Next, the 'Identify conflicts with existing projects' task contrasts scheduled tasks in existing projects with tasks in the new project that may need the same resources. These resources may be extremely sophisticated machinery, contractor specialised staff or key suppliers. If any conflicts are identified, solutions that satisfy all involved parties have to be reached. Finally, the 'Identify potential problems in scheduling and construction' task aims at identifying problems related to scheduling and construction caused by totally subcontracted tasks.

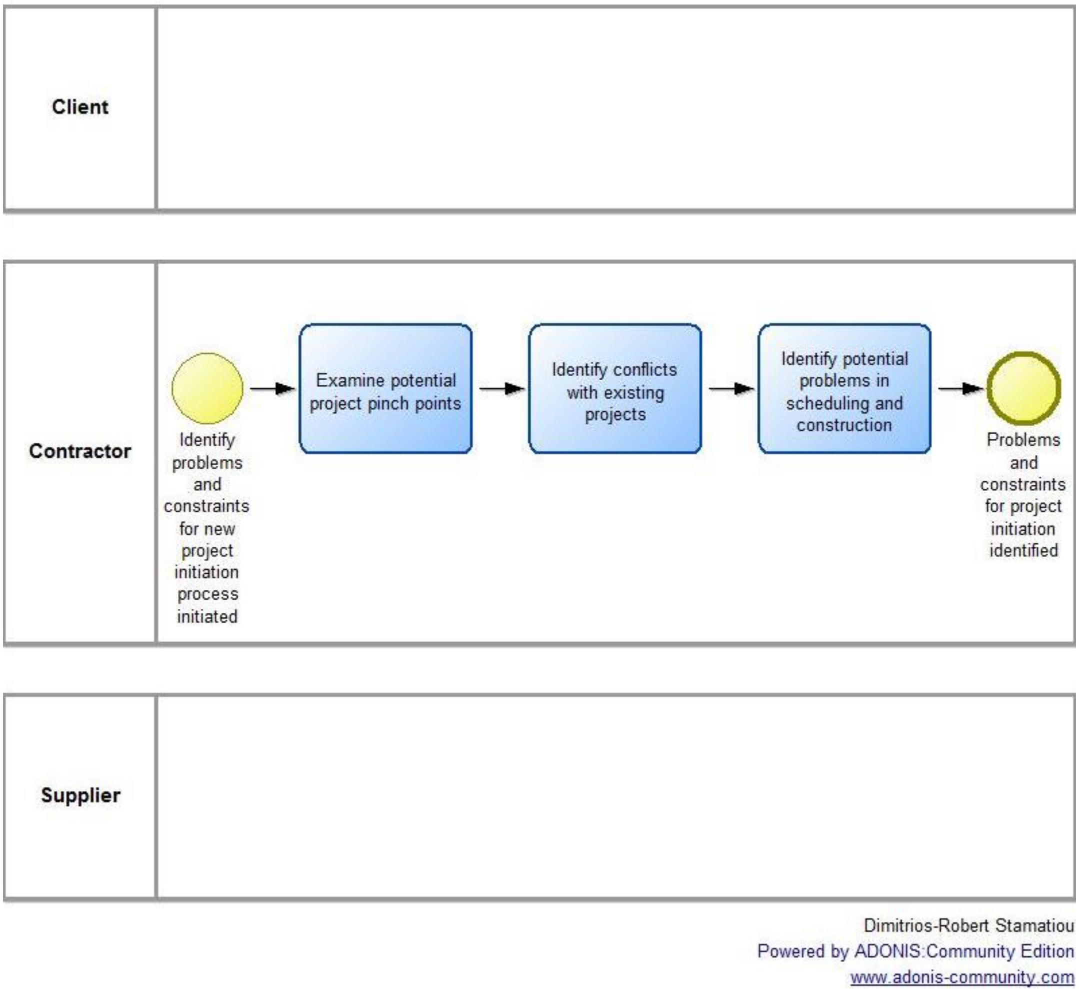

Figure 34: Identify problems and constraints for new project initiation

The last strategic process is "Develop guidelines for new project development" (**Figure 35**). The first task in this process is 'Create profitability scenarios' and aims at the creation of scenarios regarding the profitability analysis of the new project. Next, the 'Develop guidelines for the evaluation of the suitability of the new project strategy' task aims at the development of guidelines to check the suitability of the strategies under consideration for the new project. The following task, 'Determine work structuring parameters' aims at the analysis of the management considerations for work structuring. According to Mitropoulos and Sanchez (2016) these considerations include owner budget pressures, owner requirements, skill and certification requirements, economies of scale, bid package attractiveness to contractors, coordination considerations, liability considerations and transaction costs, pre-qualification requirements, and requirements for disadvantaged, small, and local contractors that may be posed by local authorities. Next, the 'Determine design requirements' task aims to provide a checklist of items needed in both the project development and the construction stages. Such a checklist should contain the following according to Juszczyk et al. (2014): land or plot development plans; architectural and construction plans; function specifications; form and construction of works in question; energy and ecology performance; technical and material solutions; guaranties of energy, water, heating and gas, and sewerage connection and the relative connection conditions; potential connection of the plot to a public road; geology engineering report; and geotechnical conditions of foundations. Finally, the task 'Develop project viability guidelines' aims at providing guidelines for the project's viability evaluation.

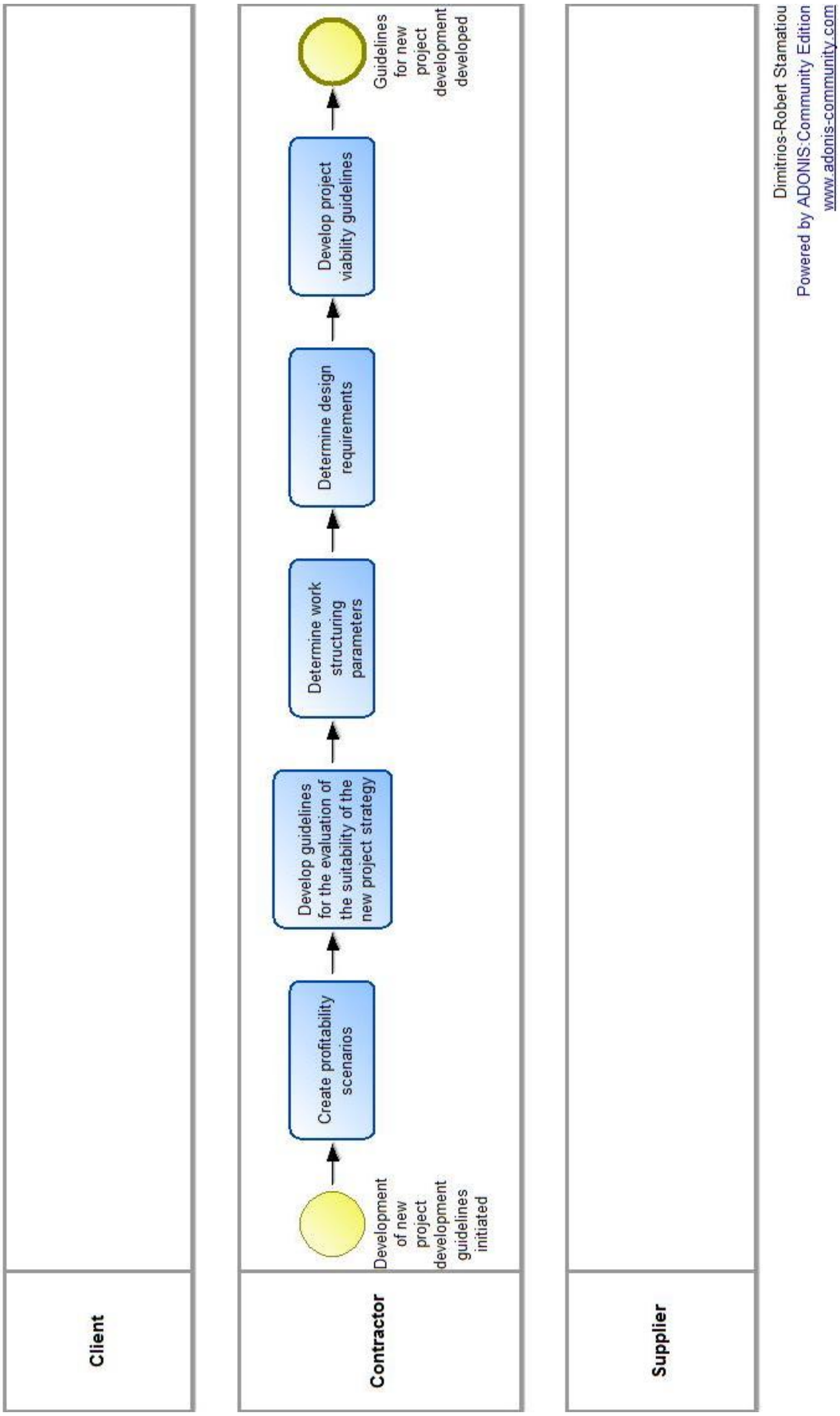

Figure 35: Develop guidelines for new project development

4.4.2.2. Operational processes

The first operational process is “Define new projects and assess suitability” (**Figure 37**) and aims to define basic and environmental information regarding the new project and assess its fit in the current project portfolio. The first task is to ‘Record ideas for new projects’. These ideas may either originate from within the contractor’s organisation or from clients and suppliers. Then the ideas are screened through the ‘Screen new ideas’ sub-processes. As seen in **Figure 36**, the sub-process is composed of five tasks based on the work of Yusof et al. (2015): ‘Classify project’, ‘Explore client value’, ‘Align with company strategy’, ‘Translate value to designers’, and ‘Internal review’. The result of this sub-process should be a documentation of the forecast of time and cost commitment, level of innovation, intended market, client needs and desires, company design strategy, and building concept definition (Yusof, An and Barghi 2015). Interviews revealed that the internal review will show if the contractor has the know-how to complete the project successfully and if the market conditions will allow successful completion.

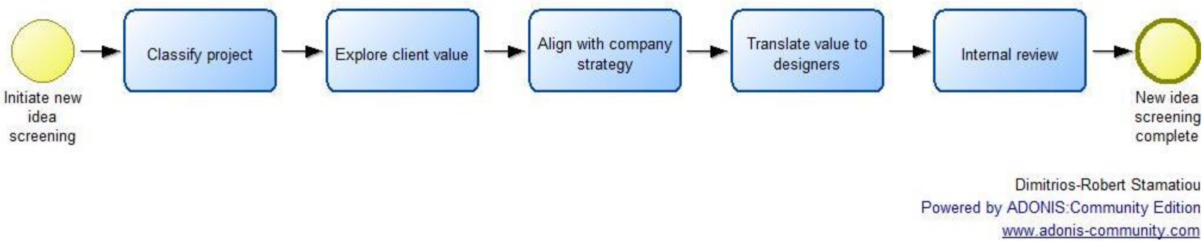

Figure 36: Screen new ideas

Next, the ‘Analyse risks of new project’ task is executed following the recommendation of Cooper et al. (1985) to subdivide a project into its major elements, and analyse the risk and uncertainty associated with each element in detail. Interviews with SMEs identified another major risk connected to private clients, that of client willingness to pay for the project. The contractor must determine the origin of the project. In the case that the project is developed internally, the ‘Evaluate market climate’ is executed in order to examine if the market climate is friendly for such an investment. In addition, SMEs analyse the chance of a new project occurring before they decide to invest in a self-financed project, as shown by the interviews. In the other case, the project originates from outside the company, and the task ‘Determine design origin’ is executed in order to establish what party is responsible for the project design. If the design is required by the contractor then the task ‘Consult with customer’ is executed and the design negotiation is initiated. Next, the task ‘Consult with suppliers’ takes place in all of the following cases: design required by the contractor, design provided to the contractor, and internally developed project. Suppliers play a critical role during the development of a new project. Liu and Zeng (2009) underline the importance of the ‘Assess Environment-Based Design’ task. This task includes environment analysis, conflict identification, and concept generation (Zeng 2004). Finally, the ‘Examine new project fit within the current portfolio’ takes into consideration all the previous tasks in order to conclude if the project presented is of interest to the company.

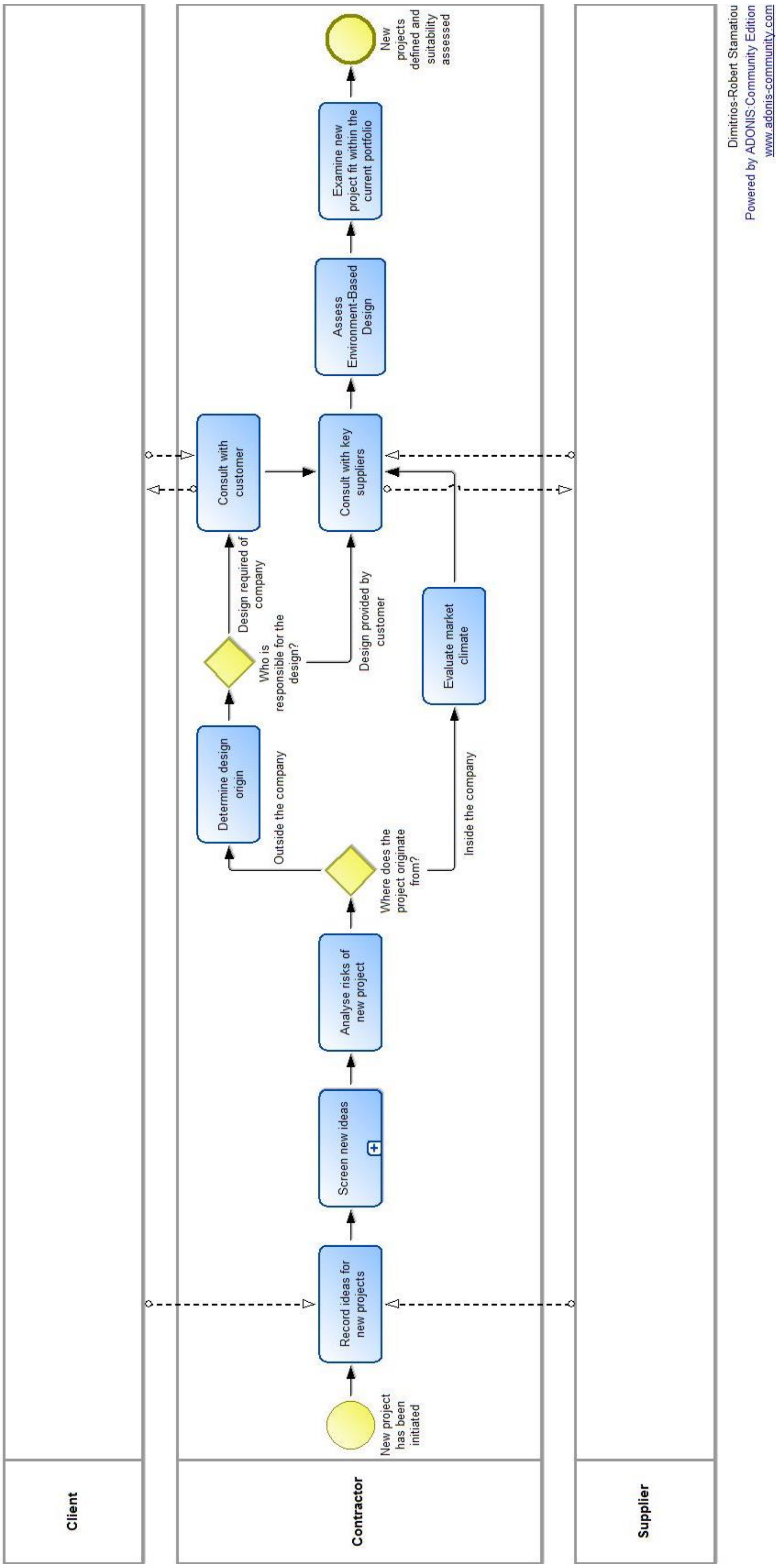

Figure 37: Define new projects and assess suitability

The second operational process is “Formation of project development team” (**Figure 38**) and it focusses on resolving problems related to the formation of the project development team. The first task is to ‘Determine level of project integration’. Ulrich and Ellison (2005) described four options in dividing design and production that can also be applied to the construction industry: internalise development and production; internalise development and outsource production; outsource development and internalise production; or outsource both development and production. The last option is described as a non- integrated or specialised supply chain structure by Hofman et al. (2009). Next, the contractor should ‘Select suppliers and/or designers that will take part in new project development’. At this point, an examination for any existing or potential problems between parties in the project development must be performed. The two main issues are cultural and geographical differences (Rogers, Lambert and Knemeyer 2004). The relative tasks ‘Create relationships that foster a common business culture’ and ‘Implement virtual team model with the use of IT’ are executed according to the project needs. Finally, the ‘Form project development team’ task takes place taking into consideration any potential implications for human resources and addressing them (Rogers, Lambert and Knemeyer 2004).

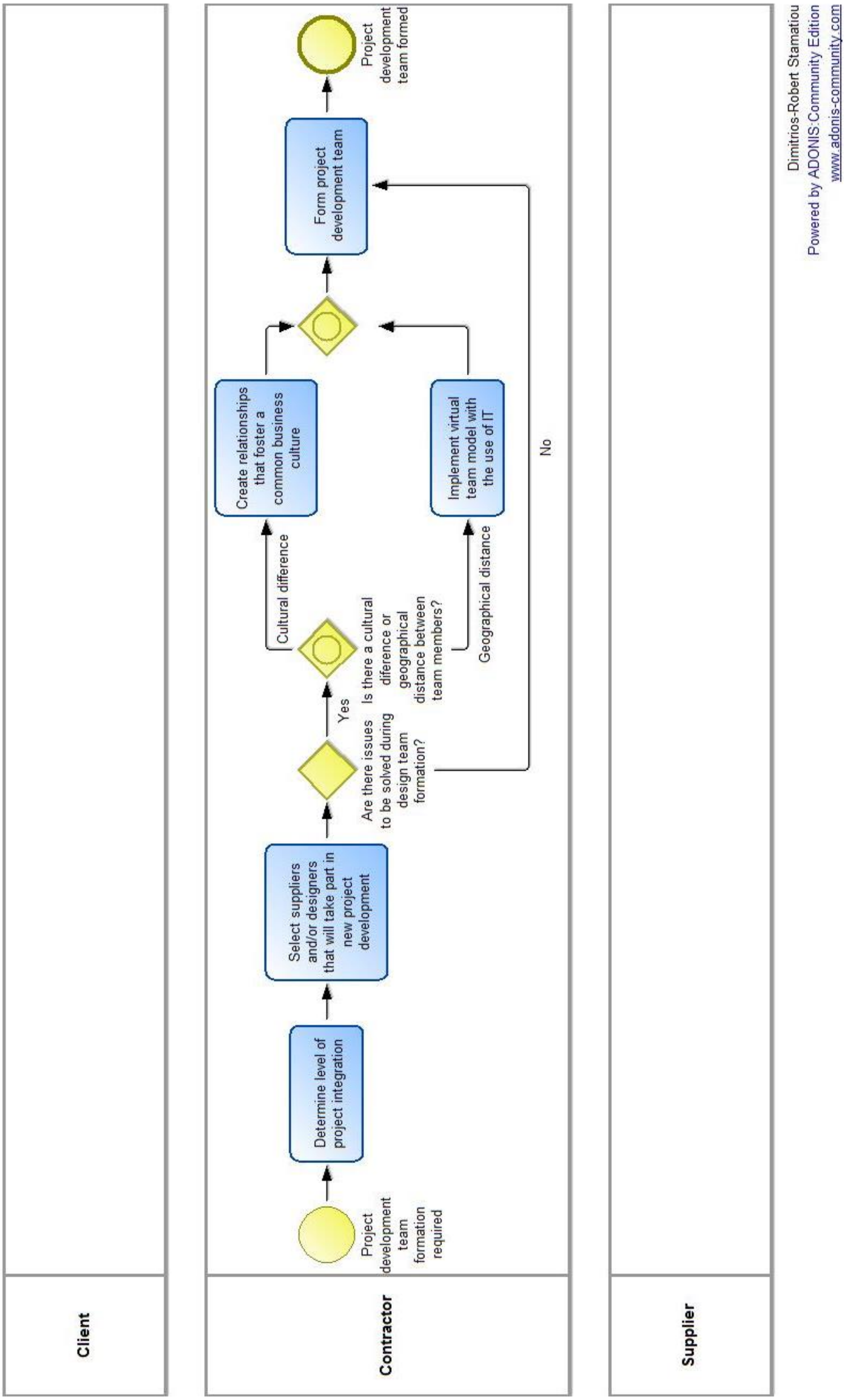

Figure 38: Formation of project development team

The third operational process is “Formalise new project development” (**Figure 43**) through which the project is conceptualised and the final designs and related costs, time and requirements are defined. According to Juszczyk et al. (2014): “*detailed design aims to complement and provide details to the construction design to the degree necessary to formulate the bill of quantities of the construction works, an investment cost estimate, to prepare a bid by the contractor (in the form of a tender cost estimate) and to facilitate the subsequent execution of the construction works*”. The first sub-process is ‘Map design scope’ as seen in **Figure 39** and contains four tasks as described by Yusof et al. (2015): ‘Identify sub-design solution targets’, ‘Decide on level of innovation to the sub-design solution’, ‘Define feasible regions of design scope’, and ‘Internal review’. The aim of the sub-process is to define the design work scope and design options.

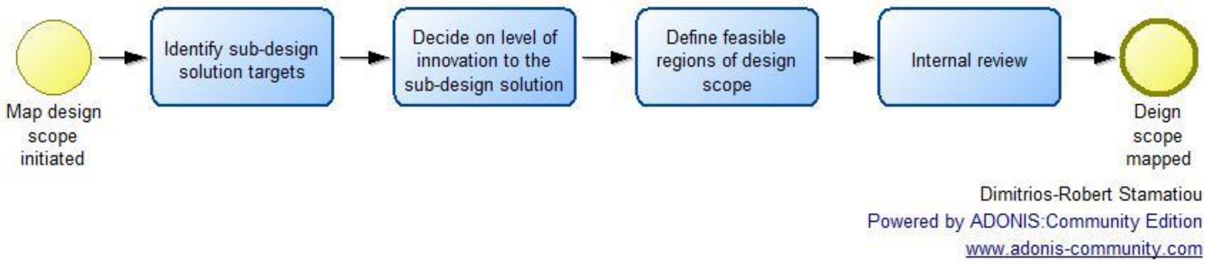

Figure 39: Map design scope

The following sub-process is ‘Develop concept design’ and, as seen in **Figure 40**, it contains six tasks as described by Yusof et al. (2015): 'Extract design concepts’, ‘Create concept design for sub-design solution’, ‘Explore the concept design for sub-design solution’, ‘Capture knowledge and evaluate’, ‘Communicate concept designs to others’, and ‘Internal review’. The aim of the sub-process is to develop different design solutions and eliminate weaker alternatives. Customer input is critical for the success of this sub-process.

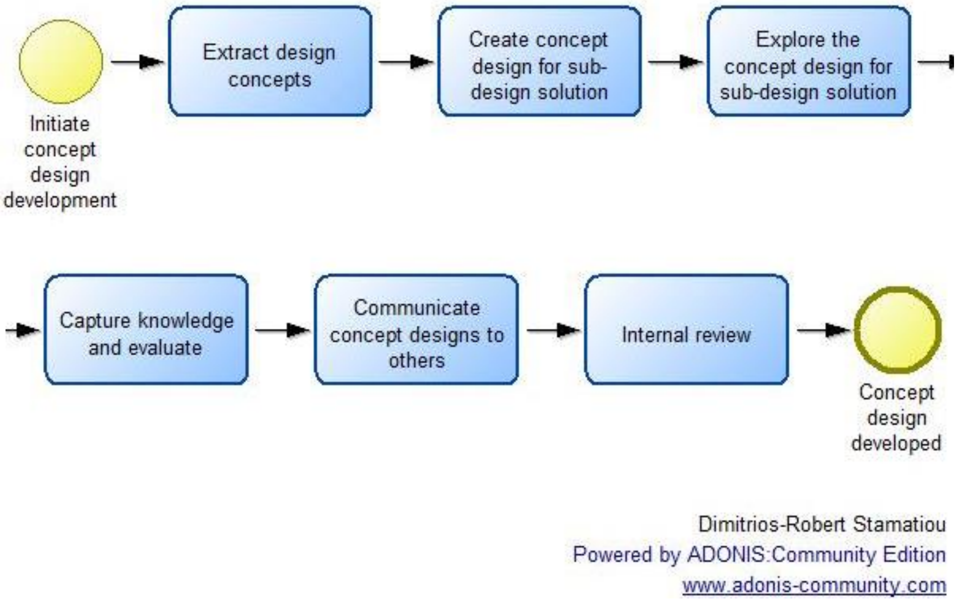

Figure 40: Develop concept design

The first two sub-processes described are executed when the design phase is included in the project. When the design phase has already been completed the process starts form the 'Integrate concept' sub-process. As seen in **Figure 41**, it contains the following seven tasks as described by Yusof et al. (2015): 'Determine concept design intersections', 'Explore possible designs', 'Seek conceptual robustness', 'Evaluate concept design for lean construction', 'Begin process planning for construction', 'Integrate the final concept design of sub design solution', and 'Internal review'. The aim of the entire sub-process is to test proposed solutions and select the best design.

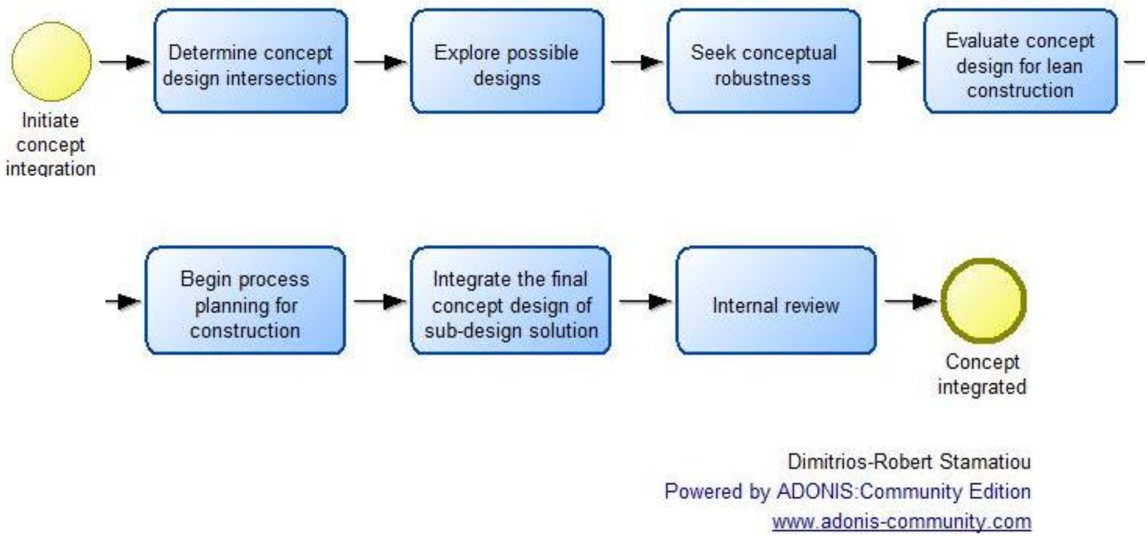

Figure 41: Integrate concept

The fourth sub-process is ‘Produce detailed design’ as seen in **Figure 42**. It contains four tasks as described by Yusof et al. (2015) which are the following: ‘Release final specification’, ‘Define construction tolerances’, ‘Full project definition’, and ‘Internal review’. The aim of this sub-process is to provide the final specification to the development team. Customer and key supplier input is critical for the success of this sub-process. This includes the selection of materials, one of the most important steps in the entire design process according to Benton and McHenry (2010).

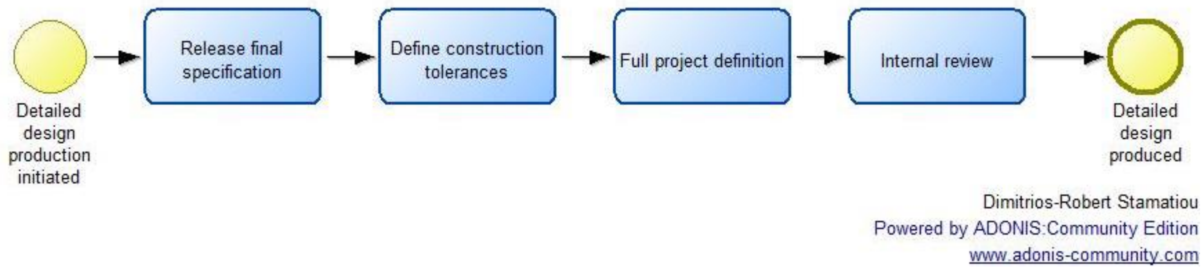

Figure 42: Produce detailed design

After the detailed design is produced, interviews showed that the ‘Perform design fine tuning’ task is executed with input from both the client and key project suppliers. This could include specifics such as changes in wiring specifications or plumbing materials that are deemed necessary by one of the parties in order to guarantee future project functionality. Next, the task ‘Log work packages’ is based on the work by Gardner (2006). First, the takt time has to be defined (Vatne and Drevland 2016). Then, work packages are created based on work breakdown and entered into a log for future use during the project construction phase. There are two sections of a work package according to Gardner (2006): “*The first section provides essential information, documents, plans, drawings, hazard analysis, turnover and quality documents etc. necessary for the construction crews to execute the work. The second section provides site-sensitive data such as detailed estimating data; project controls metrics, turnover and acceptance criteria, performance data and other information that may or not may not be issued to Construction depending on the organization*”. This may either be performed by the client, his representatives or the contractor (Mitropoulos and Sanchez 2016). All data is connected to the log number and related to each work package. Grau et al. (2014) support that “*Small work packages defined at the smallest identifiable work level* […] *provide for a flexible work planning in front of unplanned constraints and events, and hence enable the continuous utilization of work resources in a stable manner*”. March and Simon (1958) (as seen in Mitropoulos & Sanchez (2016)) propose two ways of task decomposition in work packages: specialisation by process and specialisation by purpose. Then, as interviews showed, the contractor executes the ‘Perform cost estimation’ task with the participation of key suppliers and the ‘Submit tender’ task where the client has to certify that the submission is successful. If the contractor wins the tendering process the process follows as described. The ‘Determine expectations for project completion time’ task, that is more of a negotiation for the project duration with the customer, is executed. Then, the ‘Determine profitability targets’ task is executed aiming to determine the acceptable profitability levels for the current project. The contractor has to ‘Determine resource requirements’ along with the suppliers. Finally, the level of profitability is basic input for the ‘Form budget for project development’ task that involves the negotiation of the project cost with the other project parties. If the contractor loses the tender, there are no further tasks executed.

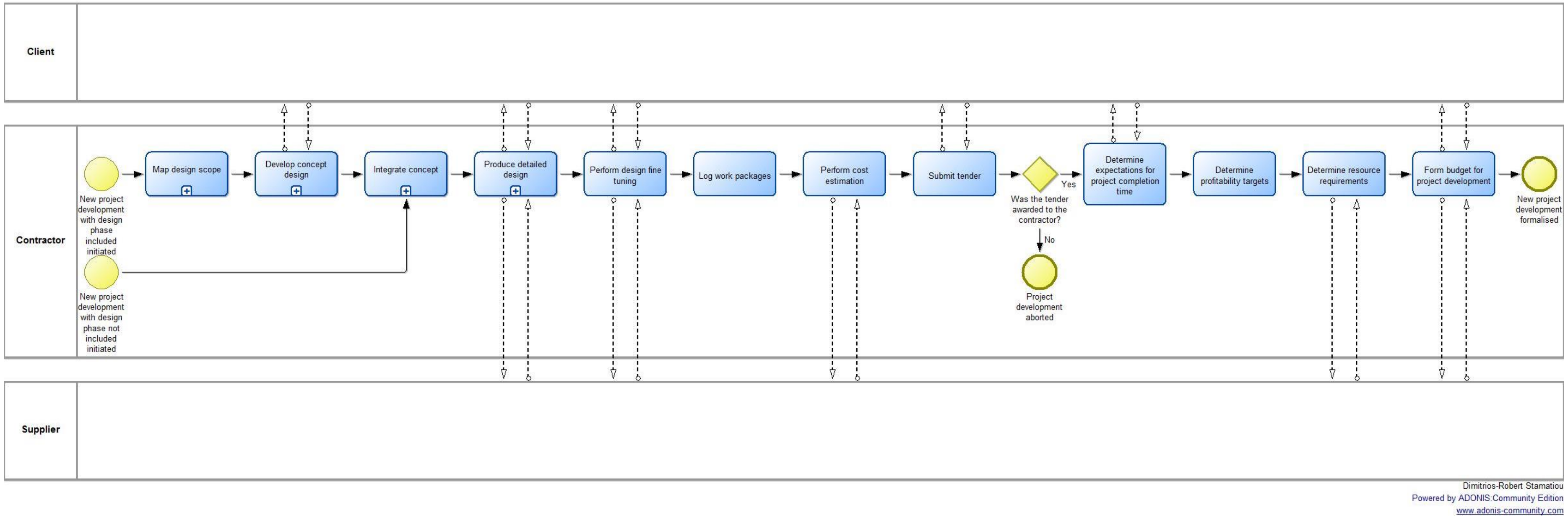

Figure 43: Formalise new project development

The fourth operational process is “Evaluate construct/subcontract decision” (**Figure 44**). After the creation of the work packages, the complexity of each task can be reduced by assigning it to a specialised actor that disposes both the relevant knowledge and resources (Mitropoulos and Sanchez 2016). This creates an additional need for coordination. According to Crowston (1991) there are three types of dependencies that have to be taken into consideration: flow dependencies between sequential activities, a set of tasks that uses common resources, and dependencies among tasks and subtasks. In addition, different activities pose different risk levels and, thus, cost levels to contractors and this calls for different levels of risk analysis in order to establish the level of contingency and the cost target (Cooper, MacDonald and Chapman 1985). These are the focus of the analysis conducted in the ‘Check need to subcontract part of the project’ task. The contractor “*should not only assess the supplier's capability and willingness to cooperate, but also provide incentives and collaboration mechanisms to motivate the supplier's action*” (Yoo, Shin and Park 2015). The following problems should be examined before any cooperation is agreed: the output of one task must be available at the time it is needed by the other task, the output must be of adequate quality, and the output must be available at the right place (Mitropoulos and Sanchez 2016). As Winch (2001) highlights, the choice to construct rather than to subcontract requires the employment of staff and investment in equipment, whereas the subcontract option is economising when no learning is required by the firm. Ulrich and Ellison (2005) listed the motives seen in **Table 13** to assist the analysis of the construct/subcontract options.

Table 13: Construct/subcontract motives

Motives for Outsourcing	Motives for internalisation	Motives for Integration
Competition among suppliers	Asset specificity and potential for hold up	Difficulty measuring the output quality of preceding activity
External economies of scale	Competitively distinctive capabilities	Task uncertainty due to endogenous factors
Responsiveness to variability in demand	Task uncertainty due to exogenous factors	
Immediate access to capabilities		
Minimisation of financial investment		

The next task is to ‘Determine potential suppliers’ for each task that has been selected for subcontracting. Then, the last two tasks are the following as described by Rogers et al. (2004): ‘Request offer submission from suppliers’ and ‘Receive and evaluate offers’ and they aim to reach a final selection of suppliers for the new project.

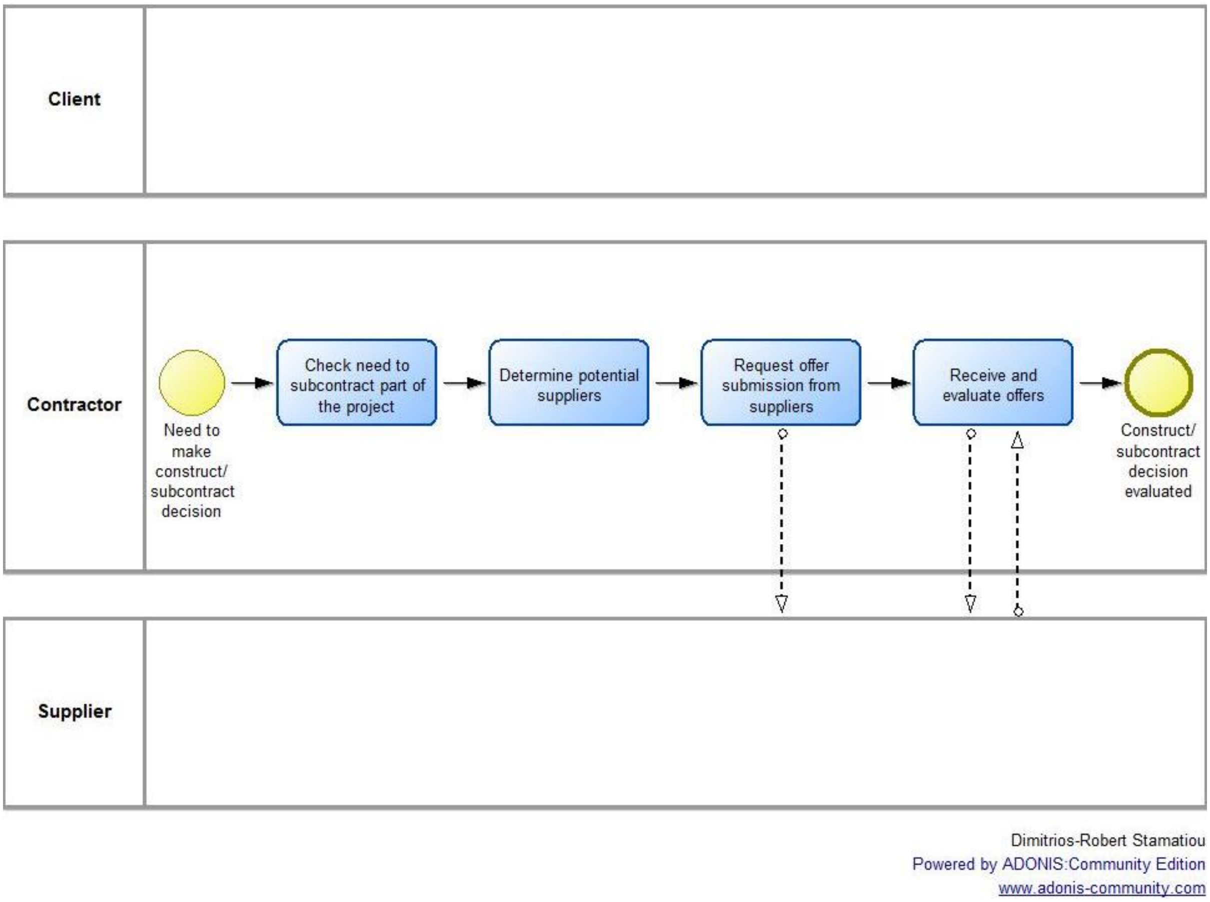

Figure 44: Evaluate construct/subcontract decision

The last operational process is “Project development and commercialisation performance measurement” (**Figure 45**). It can be executed for either previous operational process independently or for all of them collectively. The first task is to ‘Record and classify project development and commercialisation process data’ which aims at monitoring process execution and collecting the relative data generated. Data is generated during both the execution and the result of each process and underperforming or overachieving operations can be recognised through this task. Next, the task ‘Monitor project development and commercialisation performance indicators’ uses the data collected previously to compare with the performance indicators set at the strategic level. Since project development, and later on commercialisation, is a critical function for the company’s survival, the task ‘Detect main problems in project development and commercialisation’ is dedicated to identifying the occurrence and sources of design errors, their analysis and the lessons learned from these errors. Next, the ‘Draft cost and profitability reports’ task is based on the financial indicators recorded and aims at identifying the costs and the profitability that have been incurred by the execution of the entire project development and commercialisation function. Finally, the task ‘Determine performance improvement objectives’ is executed aiming at capitalising the acquired knowledge for improving performance in future projects. These objectives can be shared with other key parties of the supply chain.

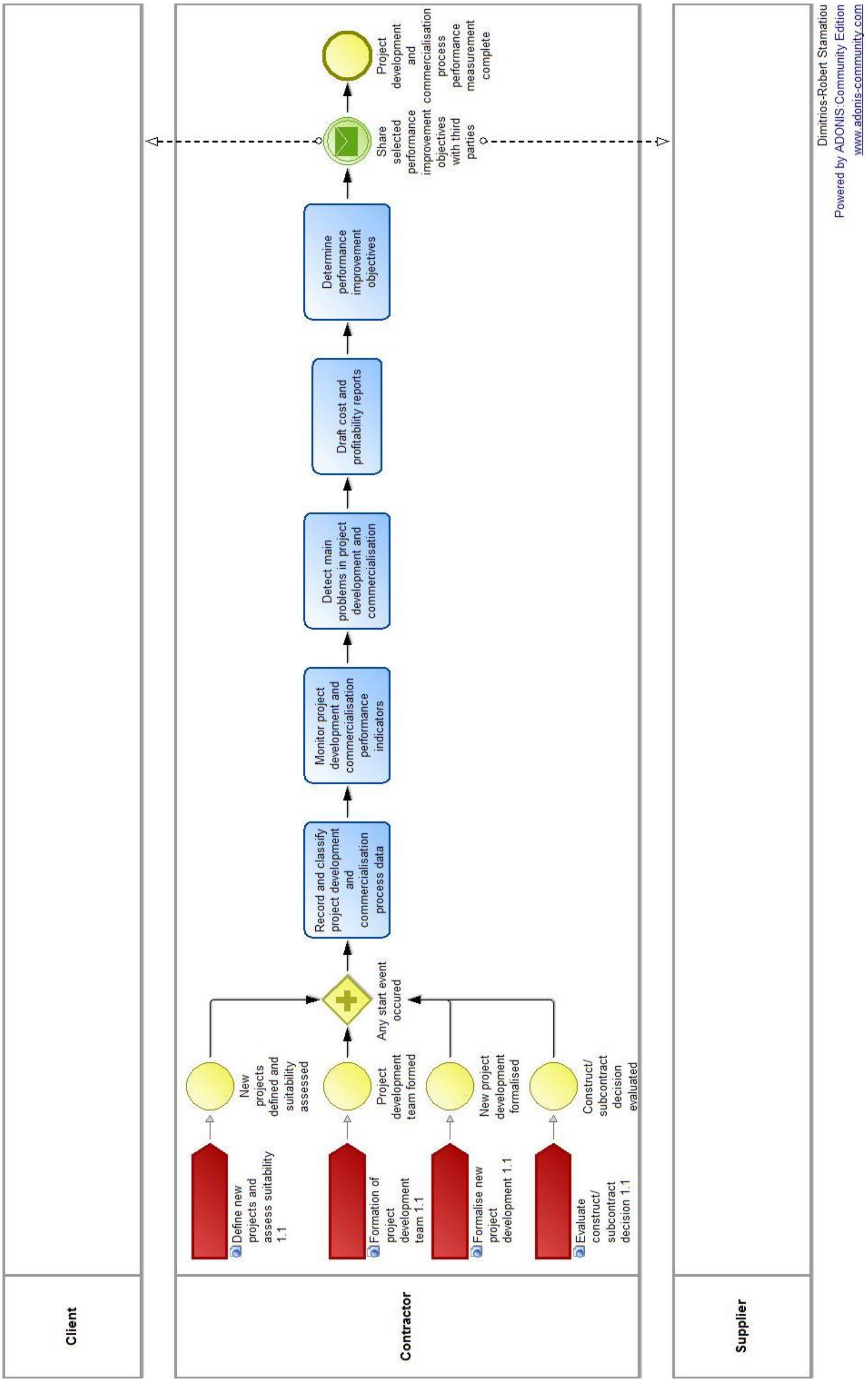

Figure 45: Project development and commercialisation performance measurement

4.5. Supplier relationship management

4.5.1. Analysis of supplier relationship management

The completion of construction projects requires many capabilities that rarely belong to a single organisation (Gann and Salter 2000). Capabilities that do not exist in contractor organisations are outsourced to subcontractors[5] and material/service suppliers. It is very rare to find construction companies that can complete all works without involving subcontractors. A prerequisite for the existence of such contractors would be employing large numbers of manpower and equipment with long idle times (Ohnuma, Pereira and Cardoso 2000). This requirement is amplified by the high complexity and differentiation of construction activities and technologies (Ronchi 2006) and the increase in specialisations in contemporary construction (Akintan and Morledge 2013). The outsourcing activity accounts for a range of 70-90% of tasks (Hinze and Tracey 1994, Mbachu 2008, Karim, Marosszeky and Davis 2006, Chiang 2009, Hartmann and Caerteling 2010), 50-75% of costs (Ibn-Homaid 2002, Caldas, Torrent and Haas 2004, Yunna and Ping 2012, Safa et al. 2014, Mirawati, Othman and Risyawati 2015), 90% of turnover (Hinze and Tracey 1994, Nobbs 1993, Vrijhoef and Koskela 2000) and affects 80% of the project schedule (Kerridge (1987) as seen in Safa et al. (2014)) depending on the type of project under study. It is important to identify the reasons behind the use of suppliers in construction projects. Enshassi and Medoukh (2008) list reasons such as shortages of skilled labour, profit maximisation, overhead cost reduction, reduction of work pressure on the contractor, reduction of complications related to monitoring and controlling quality control, safety management, and labour management for the contractor. Benefits of this practice include reducing exposure during lean periods and providing flexibility during market upturns (Gann and Senker 1998), lowering costs (Mason 2007), and decreasing construction process complexity (Leiringer, Green and Raja 2009). It becomes apparent that careful management of the purchasing function, in particular, and the supplier relationships can have a great impact on the performance of the contractor. In their study Costantino et al. (2001) found that the vast majority of contractors would subcontract a specific type of work three out of four times they came across it in order to reduce liability exposure. Furthermore, contractors have a set number of subcontractors for each type of work in order to reduce transaction costs (Bemelmans, Voordijk and Vos 2012A). The study of relationships between contractors and their upstream partners was late to take of in comparison to that of their downstream partners (Agapiou et al. 1998, Dainty, Millett and Briscoe 2001, Dainty, Briscoe and Millett 2001, Humphreys, Matthews and Kumaraswamy 2003). The relationship quality between contractors and their suppliers was found by Kale and Arditi (2001) to affect the contractor's performance and project outcomes. In general, contractors do not take advantage of opportunities to cooperate with their suppliers (Dubois and Gadde 2000). Eriksson et al. (2007) propose the adoption of long-term relationships between construction supply chain actors in order to improve innovation and value creation, but other studies (e.g. Bresnen & Marshall 2000; Bemelmans, Voordijk, Vos, et al. 2012; van Lith et al. 2015) have found that the development and management of such relationships is a challenge for the industry. In some cases contractors realised that closer working with their suppliers increased productivity (Matthews, Tyler and Thorpe 1996). Despite the fact that suppliers appreciate long-term and close relationships with contractors due to the benefits they offer (Mason

[5] In this work the term suppliers and subcontractors are used interchangeably and refer to any firm which provide materials and/or specialist service for a contractor firm in a construction project.

2007), in most cases relationships are strained and adversarial (Dainty, Millett and Briscoe 2001). In addition, contractor-supplier relationships are influenced by issues that create vicious circles of distrust (Manu et al. 2015). This results in conflicts and disputes, poor collaboration, lack of focus on client's requirements, and failure to satisfy clients' needs (Akintan and Morledge 2013). The lack of continuous relationships between suppliers and contractors is connected with the failure to improve efficiency and innovation in the construction industry (Dubois and Gadde 2000). A factor with great impact is that the majority of contractors enter strategic collaboration relationships with their clients but fail to do so with their suppliers (Akintoye and Main 2007). The importance of closer collaboration of contractors with suppliers has recently increased (Bemelmans, Voordijk and Vos 2012A) despite the fact that long-term relationships are considered difficult by organisations in the industry due to the changes in designs and project teams across projects (Bemelmans et al. 2012).

Researchers agree that construction performance is directly affected by supplier-contractor relationships (Black, Akintoye and Fitzgerald 2000, Akintoye and Main 2007). Procurement of materials and equipment has been targeted by clients as an area that can contribute to the decrease in the price of construction costs (Daneshgari and Harbin 2004). The constant change in client preferences requires contractors to utilise a broader, systematic and faster supplier selection process (De Boer, Labro and Morlacchi 2001). Clients shift responsibilities to contractors while simultaneously extending their focus from price to innovation, sustainability and speed (Bemelmans, Voordijk and Vos 2012A). Contractors transfer most of these responsibilities to their suppliers and mainly focus on managing individual suppliers and their interfaces with other suppliers. In order to succeed in this task, contractors use pyramid subcontracting with, mainly, SMEs involved (Karim, Marosszeky and Davis 2006). Despite their contribution to the completion of projects, suppliers are not always recognised for their work (Dainty, Briscoe and Millett 2001). This does not mean that suppliers are of equal nature to contractors (Mirawati, Othman and Risyawati 2015). On the one hand, main contractors have the financial capacity to handle a portfolio of administered and tendered works. On the other hand, most suppliers are described as having unstable financial backgrounds and business management practices (Abdul-Rahman, Takim and Min 2009). Currently, there is a symbiotic business relationship between suppliers and contractors where contractors purchase on credit in order to complete projects and suppliers survive on the profits they accumulate (Nicholas and Edwards 2003). Nicholas and Edwards (2003) highlight that: "*In the absence of this indirect source of liquidity, many construction projects would not be completed*". Contractors expect competitive prices from their suppliers regardless of their past in an attempt to increase cost savings over the risk of opportunistic behaviour (Hartmann and Caerteling 2010). In most cases suppliers are appointed to a contract on the basis of one-off arrangements (Pala et al. 2013). The study by Bemelmans, Voordijk, Vos, et al. (2012) shows that there is much potential improvement in buyer-supplier relationships in the industry. For example, reduction of supplier bad debts related to contractors can provide the entire supply chain with financial benefits (Nicholas & Edwards 2003). Yunna and Ping (2012) point out that most contractors neglect material management and unified management approaches for their portfolio of projects. There is a need for effective supplier selection and monitoring processes in order to align their performance with the expectations of stakeholders and project requirements (Ng and Skitmore 2014).

Before moving further, a set of definitions of suppliers, purchasing, and supplier relationship management is listed below. This is deemed necessary since suppliers and the related to them contractor functions are critical for both project completion and the industry. Enshassi and Medoukh (2008) define suppliers as "*specialists' agents in the execution of a specific job, supplying work force, besides materials, equipment, tools or designs. They respond only for the executed part of the workmanship, acting as agents of the production system of the contractor company*". Webster and Wind (1972) define purchasing as "*the decision-making process by which formal organizations establish the need for purchased products and services, and identify, evaluate, and choose among alternative brands and suppliers*". Supplier Relationship Management (SRM) is defined by Pala et al. (2013) as "*one of the components of SCM which is a company-wide business strategy to manage its interconnected, dynamic and multidimensional interactions through its various interfaces so that it facilitates development of better relationships with its suppliers*". Unlike clients, supplier categorisation is more straightforward. London and Kenley (2000) categorise suppliers based on the complexity of their product/service nature into standardised or specialised. Laryea (2009) categorises suppliers based on their selection mode as nominated, named and domestic. Both categorisations can be used simultaneously. The types of arrangements with suppliers are somewhat more complex. Vilasini et al. (2012) support that arrangements should be categorised based on decisions at project onset, mode of entry, functional participation, payment methods and supplier capabilities.

In order to develop the best supplier management techniques, it is important to understand how suppliers view contractors and identify some of their main characteristics. This is imposed by the fact that there is a trend to increase spending on suppliers. Increased spending on suppliers provides opportunities for better cooperation (Bemelmans, Voordijk and Vos 2012A). Suppliers' contribution to capital risk, resources, managerial effort, and business expertise is very significant in the industry (Enshassi and Medoukh 2008). But suppliers have many concerns about their contributions and face their relationships with contractors with mistrust and scepticism (Dainty, Briscoe and Millett 2001). The studies by Dainty et al. (2001) and Tommelein and Ballard (1997) revealed that suppliers believe that contractors abuse their contributions to a project in order to increase their own profits without respect of the supply chain. Some of the practices by contractors that enhance mistrust for the suppliers include late payments, charging fees in order to tender for work, awarding contracts solely on the basis of lowest price disregarding best value, suicide bidding and demanding retrospective discounts and cash rebates (Arditi and Chotibhongs 2005). In addition, in the event of delays at the project, suppliers are left facing a tuple of liabilities that they cannot cover due to a the non-existence of pre-ascertained liquidated damage (Greenwood, Hogg and Kan 2005). Suppliers feel these contractor behaviours deteriorate during economic downturns (Knutt 2012). Despite the views both sides hold, it is common to find that they work together in more than one project (Håkansson, Havila and Pedersen 1999). There are of course differences in the way contractors view their suppliers and vice versa that can be attributed to cultural causes. For example, most of the idiosyncrasies referenced up to now relate to the western construction industry, whereas in other industry regions, such as the Japanese described by Reeves (2002), suppliers may have different relationships with their contractors. Reeves (2002) found that suppliers in Japan prefer to work with a singular contractor exclusively.

The nature of work in the construction industry means that contractors work on credit. This means that suppliers have to make sure that credit repayment is not enforced unduly fast in order to avoid potential debtor insolvency (Nicholas & Edwards 2003). In addition, suppliers have to be able to deliver their materials or services to the contractor when promised in order to ensure they do not lose any income due to delays (Benton and McHenry 2010). It was found by Lowe (1987) that despite the fact that suppliers operate in uncompetitive market structures, they are unable to take advantage of their monopolies due to legislation and contractor power. Contractor power is amplified through the tendering process. Laryea (2009) defines a tender as "*an offer that could lead to a binding contract when accepted in its original terms*". Tenders are binding when the process is finalised, quotations are not. Contractors should be very careful when selecting the appropriate price acquisition method in order to avoid unpleasant surprises during the project. Contractors must also be aware of the fact that a supplier may be approached by competitors for a project (Shash 1998) and that suppliers in these cases may operate opportunistically (Ray et al. 1999). In most cases, contracts are awarded and executed on the basis of physical production and compensated at a fixed price, thus suppliers tend not to pay the required attention to quality and waste (Ohnuma, Pereira and Cardoso 2000). This problem is not one sided as contractors mainly pay attention to price during supplier selection and pay less attention to technical expertise, quality and cooperation (Hartmann, Ling and Tan 2009). In many cases, suppliers cannot cope with the quality management demands of a project and their failure to adopt technological advancements or invest in developing their human resources leads to many problems in their relationships with contractors (Lin and Gibson 2011). In contrast, suppliers believe that the main reason for poor quality is that communication and understanding by contractors is poor (Yik et al. 2006, Chiang 2009). It is common to find that suppliers have a disregard for health and safety regulations on the work site (Arditi and Chotibhongs 2005, Chiang 2009). According to contractor claims, suppliers tend to employ inadequate workmen at the project site that cause many problems to the contractor-supplier relationship (Johansen and Porter 2003). All these friction points may lead to adversarial relationships and the relationship may affect the project in some cases (Wood and Ellis 2005). These adversarial relationships make it hard to involve suppliers in the value-creation process (Bemelmans et al. 2012), but there is evidence that contractors are attempting to stretch their contractual relationships along the supply chain (Pala et al. 2013).

Effective management of buyer-supplier relationships is important in any industry. As Bensaou (1999) stresses out, effective and efficient management of a portfolio of relationships is required for successful supply chain management. This requires vast supply bases to become a thing of the past. Changing the way relationships are handled is not an easy task, but with the reduction of supply bases come opportunities for more intense supplier development (Harland 1996). Despite the importance of suppliers, not all relationships are the same. In addition, it is utopic to think that all suppliers in a project can be managed by the contractor (Holti, Nicolini and Smalley 2000). Boes and Holmen (2003) ascertain that, depending on supplier capabilities, different management mechanisms may be more appropriate. In their work, van Lith et al. (2015) list the aspects that contractors need to develop in buyer-supplier relationship management as follows: managing buyer-supplier relationships, improving supplier performance, optimising supply base, and integrating the supplier in the value creation process. Adopting a relationship-centric perspective can lead to more effective operational and strategic engagement with suppliers (Pala et al. 2013). It is proposed in the literature that some arms-length relationships can be turned to more collaborative ones. An easy step that can help enhancement of collaboration is selecting certain suppliers as “preferred suppliers” with whom annual contracts are signed and extra quality involvement is required (van Weele 2009). Despite the fact that close relationships are connected with high-quality, on-time delivery and low cost (Greenwood and Wu 2012) they are not a panacea to be adopted in all purchasing situations (Bildsten 2014). The most important factor that will lead to the appropriate relationship type with a supplier is asset specificity (Walker and Weber 1987). Who controls asset specificity will dictate the balance of power in the relationship. Another factor encouraging closer relationships with suppliers is that when contractors enter new relationships it is hard for them to assess subcontractor intentions and capabilities (Gulati 1995, Hartmann and Caerteling 2010). Using a portfolio approach allows the investment of resources in more efficient and effective ways and leads to the development, management and optimisation of relationships with strategic suppliers (Zolkiewski and Turnbull 2002). There are many supplier relationship management problems that need to be overcome. For example, in the study of the Dutch construction industry by Bemelmans, Voordijk, Vos, et al. (2012), the following problems were found on the contractors side: lack of a formal and documented supplier selection process focussed on the current needs and capabilities of the company; lack of a supply base optimisation plan based on a supplier rating system; lack of a formal definition in the purchasing policy of which category of suppliers should be selected for partnerships; lack of a formal, documented and communicated improvement plan of their own operational processes; unwillingness to take the first steps to create a policy/procedure for the value-creation process; lack of a formal supplier performance measurement system; and lack of a proactive mind-set toward suppliers in order to develop suppliers in the desirable direction. Contractors may select suppliers either from their supply base or from the open market, but need to commit to collaboration in both cases (Ronchi 2006). In some cases, contractors may want to develop supplier relationships much further than usual. In order for such attempts to succeed, contractors have to pay attention to the following elements listed by Krause and Ellram (1997): effective communication, top management involvement, cross-functional buying firm teams, price versus the total cost of ownership, long-term perspective, large percentage of supplier’s annual sales, supplier evaluation, and supplier recognition. In addition, it is good practice to integrate these suppliers in the design phase of the project in order to minimise possibilities of adversarial relations during the project (Gadde and Dubois 2010). Repeated integration of suppliers in the design phase can lead to smoothing of the learning curve and the value-creation process (Bemelmans et al. 2012). In contrast to traditional project based collaboration, repeated and long-term collaboration can help contractors maximise the benefits of supplier’s knowledge and competences. Supplier product knowledge, safety knowledge and experience may lead to increased efficiency in a project and the knowledge acquired through experience percolates in the specific organisational network (contractor, suppliers of supplier, service providers to the supplier) (Daneshgari and Harbin 2004).

There are many problems related to the management of the upstream supply chain by contractors. One of the main issues is that their management of suppliers does not extend beyond immediate subcontractors (Pala et al. 2013) as subcontractors do not have any control over their own subcontractors or suppliers (Vrijhoef & Koskela 2000; London & Kenley 2000; Humphreys et al. 2003; Briscoe & Dainty 2005; Bemelmans, Voordijk & Vos 2012; Bemelmans, Voordijk, Vos, et al. 2012). The increased complexity of contemporary construction projects (Ahuja, Dozzi and AbouRizk 1994) along with improvements in procurement systems have constrained contractors to managing supplier interfaces rather than executing projects (Humphreys, Matthews and Kumaraswamy 2003). This has given ground to an increase of the practice of risk transfer to upstream supply chain parties which entails many problems such as decrease of specialism on the contractor's side, poor communication along the supply chain and loss of control over sourcing processes (Chiang, Tang and Leung 2001). It is common to find that main contractor-supplier relationships are tense and adversarial (Latham 1994). The contractor has to manage many relationships during project execution, on both sides of the supply chain, but most of them are on the supply side. The construction and delivery processes are highly fragmented, comprised by several subcontractor tiers, and integration of the involved parties is problematic (Dainty, Briscoe and Millett 2001). In addition, the extended use of traditional procurement methods still leads to separate planning and development of the project schedule (Akintan and Morledge 2013). This would be less of a problem if effective communication was achieved between parties, but this is not the case. Ineffective communication, along with poor cooperation and lack of trust are the main reasons adversarial relationships arise (Chan et al. 2004). The phenomenon of blame culture leads to a breakdown in trust between the contractor and his subcontractors (Akintan and Morledge 2013). Further problems that affect trust in relationships between the two parties are late and unfair payments, poor health and safety standards and unacceptable workmanship (Arditi and Chotibhongs 2005). Focusing on contractors, a survey by Ray et al. (1999) in Australia provided evidence of unethical behaviour by contractors. For example, contractors have been found to accept lowest price tenders even if they know there have been pricing errors by subcontractors leading to many problems during the payment phase (Dainty, Briscoe and Millett 2001). In another study by Briscoe et al. (2004), there was evidence of superficial contractor efforts to collaborate with subcontractors just so they can achieve inclusion on client lists that had strict selection criteria. Further proof of contractors' bad attitude towards their suppliers is the fact that fair payment promotion is still being debated in both the academic and practitioner literature regarding the UK construction market (Nichol 2013). In addition, as Akintan and Morledge (2013) highlight, harsh contract terms enforced by contractors in subcontractor agreements exhibit the negative attitude contractors have towards their subcontractors. Such clauses are found to destroy long-term relationships through a single subcontractor error (Dainty, Briscoe and Millett 2001) and deter compensation seeking by subcontractors even in cases they are entitled to it (Akintan and Morledge 2013). Traditional procurement allows such behaviours and attitudes because subcontractors are not included, and thus protected, in the main client-contractor contract. Decisions made by contractors were found to be single-sided and undisputable and this leads subcontractors to opaque practices such as not sharing other project commitments with contractors (Akintan and Morledge 2013). These practices do not encourage collaboration and can lead to trust breaking down. When Dainty et al. (2001) examined the view of subcontractors towards their relationships with contractors they found out that: smaller supply chain companies thought programming times were often unrealistic and lead to poor quality buildings and latent defects; risk was passed down the supply chain instead of being shared by the supply chain; little or no effort made to align systems between companies; lack of effort on behalf of main contractors to show a two-way commitment in investing in their supplier relationships; contractors shared low quality information; contractors displayed a lack of willingness to develop an equitable 'involvement climate' between the parties; aggression towards subcontractors and suppliers by contractors and exclusion from early project involvement; lack of understanding and empathy towards SME needs; focus of site management teams on project completion at shorter times instead of effective coordination and integration of specialist trades; and rare subcontractor appraisal for value adding innovation on their behalf. These problems in relationship practices can lead to the suggestion that contractors do not truly intend to invest in cooperative relationships (Eriksson, Dickinson and Khalfan 2007). Contractors are in a powerful position in the supply chain having direct contact with the client and good quality information on the available budget. This enables them to enjoy any cost reductions that will occur through their interaction with their suppliers. It was found that managers in contractor organisations only consider price and quality criteria to select suppliers without performing structured evaluation of the offers though a methodical selection process that can guarantee evaluation efficiency (Schramm and Morais 2012). This situation is damaging the image of the industry. There is a change in mind-set required and it is encouraging to find reports in the literature that change is imminent. London et al. (1998) found that it is mainly larger organisations that take responsibility for managing change in the industry with suppliers and subcontractors having little to no input. This find has two readings. First, construction companies have recognised that change is required in order to improve relationship quality but they face the problem that they do not have the required knowledge (due to time constraints or ignorance of such techniques) to improve their suppliers' performance to match their requirements (Schramm and Morais 2012). Second, the low levels of input by the suppliers and subcontractors are attributed to the use of the traditional construction procurement methods that inhibit value improvement and integration with the rest of the supply chain (Akintan and Morledge 2013). The concept of partnering has been proposed in order to help construction organisations improve their relationships and practices. Ng et al. (2002) proposed the following means for both sides in order to avoid problems when attempting to improve relationships: full commitment to the process and attitude of project partnering; ensuring all stakeholders have a complete understanding of project partnering requirements; willingness to show personal relations with the head contractor; encouraging mutual acceptance of project partnering implementation; compromising regulations and organisational structure; implementing less restrictive tendering arrangements; empowering representatives to make effective decisions; inclusion of design consultants in the arrangement; providing comprehensive training and guidance; facilitating and implementing team goals monitoring; facilitating and implementing a rigid problem resolution process; and employing an independent facilitator throughout the entire project.

Trust, as with clients, is a parameter of paramount importance in the successful management of relationships with suppliers, especially because of the increased chances of a repetitive relationship in a specific market. Repeated interaction between parties may act as proxy for trust development because of knowledge of the other party's practices (Gulati 1995). According to Akintan and Morledge (2013), main contractors tend to lack confidence in their suppliers and interfere with their operations onsite increasing the potential for conflicts. Trust is bidirectional. Hartmann and Caerteling (2010) believe that long-term relationships between the two sides should allow trust to develop. On the contractor's side, trust (along with attitude and culture) is considered by practitioners as a qualitative aspect that has more bearing than cheapest price alone when initiating a relationship (Pala et al. 2013). Basing a business relationship on trust yields benefits in the long-term such as effective communication, relating and knowledge of important parameters (Xu and Smyth 2015). Effective communication, in particular, is the most influential condition for successful partnering (Doloi 2009), in case relationships are to be furthered. In addition, trust is essential if contractors want to achieve high levels of flexibility and ensure reliable information flows along the project supply chain (Swan et al. 2002) as it allows the selection of the best governance mode for each case (Gulati and Nickerson 2008). Manu et al. (2015) identified the following factors that influence trustfulness and trustworthiness of both main contractors and subcontractors: change management process, payment practices, economic climate, perception of future work opportunities, job performance, and project-specific circumstances. In addition, Manu et al. (2015) identified the following factors affecting the level of trustfulness of the contractor: economic climate and project specific context, especially the restrictions in subcontractor selection posed by the project context. Factors that lead to the breakdown of trust by contractors were listed by Akintan and Morledge (2013) as: delayed payments to subcontractors, disruptions of subcontractor work plans, subcontractor exclusion from decision making processes, and imposing harsh contract terms in subcontract agreements. A common practice followed by contractors is to request a renegotiation of tendering prices provided by suppliers upon project contract nomination (Enshassi and Medoukh 2008). This practice severely impacts the establishment of trust, even if contractors stay with the preselected subcontractors for the construction phase. There is a sensitive balance between price and trust when selecting subcontractors where repeated relationships build trust that work will be executed seamlessly but favourable and non-opportunistic quotes are required for cooperation to be considered (Hartmann and Caerteling 2010). Despite the fact that the level of trust and the cost of transactions are interrelated (Ouchi 1980), other factors such as quality, technical know-how and cooperation are also considered when the choice of suppliers is made (Hartmann and Caerteling 2010). It is easy to see how reputation is affected by trust. Good performance can induce trust (Barney and Hansen 1994) whereas opportunism will prevent trust from forming (Rooks, Raub and Selten 2000) and harm reputation. Yet, in the dilemma between trust of a known supplier and reputation of a new supplier (given price differences are small) contractors should keep in mind that, as Jones et al. (1997) point out, reputation can be inaccurate, misinterpreted or given a false colour.

Construction projects require the input of many material suppliers, work force suppliers and subcontractors. This makes sourcing for this input a very complex task. As described by Ronchi (2006), there are two approaches to sourcing for a project; internal (stable supply base, selection based on private negotiation) and external (volatile supply base, selection based on contracting pressure) sourcing and the selection of each is based on the strategic approach adopted. He collected empirical evidence that pointed to four sourcing models for contractors based on the characteristics of their supply base, namely Hierarchical Open Sourcing model, Collaborative Internal Sourcing model, Connected Open Sourcing model, Disconnected Internal Sourcing model. Selecting the number of sources is another complex decision, since multiple and single sourcing have different characteristics, downsides and benefits. On the one hand, benefits associated with multiple sourcing are competition, assured supply and undisrupted supply of bulk materials along with improved market intelligence and improved supplier appraisal effectiveness (Benton and McHenry 2010). Other benefits associated with multiple sourcing in the manufacturing industry are lower prices for clients and production flow security (Kawa and Koczkodaj 2015), benefits that can also be reaped in the construction industry. The main weakness associated with multiple sourcing is high operating costs to maintain relationships such as information system maintenance cost, controlling, negotiation, audits and setting cooperation conditions (Choi and Krause 2006). On the other hand, single sourcing is associated with large volume certainty, lower costs for the supplier, increased cooperation and communication, and development of win-win relationships (Benton and McHenry 2010). There are two functions related to sourcing: enquiring and purchasing. Enquiring by contractors is based on experience instead of systematic evidence and this poses many problems (Laryea 2009) especially problems related to the large percentage of costs caused by the labour involved and the volume of enquiry documents (Bemelmans, Voordijk and Vos 2012A). Purchasing follows enquiring and "*includes decisions on whether to use a new subcontractor, a new component or a new process*" (Bildsten and Manley 2015). The purchasing volume in the industry is very high in relation to turnover (Hartmann and Caerteling 2010). There are cases where material purchases require the additional purchases of equipment (Benton and McHenry 2010). It becomes clear that, through the purchasing function, suppliers have a large impact on the performance of the project (van Lith et al. 2015). In addition to performance, quality (Proverbs and Holt 2000, Karim, Marosszeky and Davis 2006) and time (Kumaraswamy and Matthews 2000) are other parameters influenced by purchasing. Quality depends on the specifications of the client and the compliance of the supplier to these specifications and, according to contractors, it is rarely a problem if the supplier complies (Benton and McHenry 2010). Robinson et al. (1967) identified three purchasing situations: new buy, modified rebuy and straight rebuy. There are different levels of effort related to each purchasing situation and each category has a different impact on the cost of projects (modified rebuys account for the majority, straight rebuys account for around 10%) (Bildsten and Manley 2015). In practice, supplier selection is based on activity specificity, work complexity and nature, and prior experience with the suppliers (Enshassi and Medoukh 2008). Unfortunately, cost-saving/value-adding options and the opinion of the designer are not always considered, especially in straight rebuys (Bildsten and Manley 2015).

Subcontracting is a deeply rooted practice in the construction industry. This can be attributed to the specialist nature of most works in a construction project (Yik et al. 2006). In addition, large firms in the industry strategically select emphasising on flexibility in order to gain competitive advantage (Winch 1998) and to minimise fixed assets (Arditi and Chotibhongs 2005). This selection helps them survive the volatile business cycle of the industry (Dainty, Briscoe and Millett 2001). Unlike other industries, construction companies, main contractors in particular, are unable to use techniques such as stock management to counter fluctuations (Hartmann and Caerteling 2010). Subcontracting is a risk reduction selection that allows companies to react to the volatility of their portfolios in a safe way (Hartmann and Caerteling 2010, Sacks 2016). Subcontracting has become even more popular since integrated contracts with clients have shifted the majority of risks to the main contractor (Mirawati, Othman and Risyawati 2015). Advantages of subcontracting include improved flexibility, increase of productivity, improvement of final product quality, elimination of labour and equipment idle time, easy cost control, delays' reduction, encouragement of quicker task completion, externalisation of risky activities and finances, minimisation of worker costs, and adjustability to market demands (Ohnuma, Pereira and Cardoso 2000, Manu et al. 2013). In many cases, especially in a specific market context, subcontractors may be approached repetitively. It is common to find that purchasing organisations (at an organisational or individual level) and individuals prefer repeating business with parties they had good prior experiences with (Kamann et al. 2006) because they expect that these parties continue to have the ability to provide a quality product/service (Benton and McHenry 2010). The potential for future works should be exploited by actively managing relationships with suppliers in order to improve project performance (Dyer and Ouchi 1993, Håkansson and Snehota 1989, Walter 2003, Sjoerdsma and van Weele 2015). The fact is that all relationships with suppliers should be actively managed, but there should be an adjustment of behaviour according to prior experiences. As Kamann et al. (2006) underline, the basic parameter to be considered for behaviour adjustment is past experience. In general, behaviour is affected by the power balance in the market. Factors that determine the power position in the supply chain, according to Manu et al. (2015), are the following: the standardisation/commoditisation extent of a product/service, the number of available suppliers, the number of available clients to the supplier, change costs for both parties, and the level of information asymmetry. Both parties, but especially contractors, have to take these factors into consideration when attempting to manage their suppliers. The nature of handling the network relationships and the selection of collaborative partners are critical in order for any organisation to select a competitive behaviour with which to approach their clients (Harland 1996). Behaviours are stratified in a mature organisation and there are four discrete levels: project level, regional level, business unit level and corporate level, and at each level the purchasing functions are carried out on a different basis (Bemelmans et al. 2012). This requires the existence of a robust strategy that will dictate how relationships are to be managed at each level.

Cooperation is unavoidable and contractors have to make the most out of each cooperative transaction. According to Thompson and Sanders (1998), cooperation and collaboration signify different degrees of alignment/integration, where collaboration portrays a higher degree of integration than cooperation. Kamann et al. (2006) found that repeated cooperation with suppliers that has a future outlook can reduce potential problems and conflicts. They also identified the causes of potential problems in opportunistic behaviour. Such behaviour is demonstrated by contractors that end effective relationships just because a new supplier is cheaper (Hartmann and Caerteling 2010). Contractual frameworks in traditional market relationships make collaboration difficult because they form barriers between suppliers and contractors and enhance opportunism (Johansen and Porter 2003). This opportunism can be attributed to the relatively unmanaged use of subcontracting in the industry (Cox, Ireland and Townsend 2006A). Typically, relationships are cost driven (Greenwood 2001), and less attention is paid to quality, cooperation and technical know-how (Hartmann and Caerteling 2010). But, there are signs that contractors wish to form closer relationships with their suppliers (Bemelmans, Voordijk and Vos 2012A). Despite the fact that most contractors are not interested in a collaborative relationship (Eriksson, Dickinson and Khalfan 2007), it is clients' wishes to do so that create the need to do so (Akintan and Morledge 2013). The use of relational contracts can build trust though the feeling of fairness (Kadefors 2004) and can lead to higher performance in the project (Pocock et al. 1996, Pocock, Liu and Kim 1997, Franz and Leicht 2012). Fairness and trust leads to more harmonious relationships that improve efficiency and performance of the supply chain because parties can share resources and make plans in a collaborative spirit (Rowlinson and McDermott 1999). The level of interaction between parties affects the strength of collaboration, problem solving attitudes, and supplier involvement in the design phase of a future project (Ronchi 2006). Both sides of such a relationship must accept that some of their profits may be at risk instead of attempting to ensure their profit over the others (Akintan and Morledge 2013). The level of collaboration with suppliers determines the purchasing maturity of a contractor (van Lith et al. 2015). The following four dimensions of integration described by Eriksson (2015) can be used to determine the level of maturity in relationships: strength, scope, duration, and depth of integration. Especially in a climate of rich work quantities, suppliers may be tempted to stay exclusive to their contractors (Reeves 2002) and reap many benefits that stem from supply chain integration (Briscoe, Dainty and Millett 2001, Dainty, Briscoe and Millett 2001). Strategies that build on long-term relationships, such as partnering and alliancing, have become paradigmatic in both literature and practice (Anvuur and Kumaraswamy 2006). Such practices go beyond normal market transactions and have long-term applications that lead to cost advantages and other benefits (Porter 1985). Through repeated successful partnerships the relationship becomes more robust in case of unexpected events (Rousseau et al. 1998) and both sides can learn how their counterparts behave and use this predictability to offer better conditions to each other (Rooks, Raub and Selten 2000). Furthermore, according to Tang et al. (2006), the application of partnering can lead to improvements in risk and total quality management. On the one hand, risk sharing is ensured by the contract provisions (Matthews and Howell 2005) and, on the other hand, total quality management is improved through the integration of suppliers in the contractor's operational and value creation processes (Bemelmans et al. 2012). When partnerships become long-term strategic partnerships, the relationship characteristics increase in terms of longevity, volume, complexity, integration and strategic importance (Pala et al. 2013). A learning culture should be created in order to foster partnering (Cheng et al. 2004) since such relationships impact system and operational capabilities (Monczka et al. 1998, Sukati et al. 2012). Alliances are another collaborative method used that produces superior client satisfaction Kwok and Hampson (1997). Unlike partnerships though, alliances rarely develop into a relationship that lasts beyond a specific project (Brown et al. 2001). Main contractors rarely see benefit in such relationships, especially with suppliers with whom they rarely cooperate (Dainty, Briscoe and Millett 2001). Supplier integration through alliances have improved performance in certain projects (Miles (1998), as seen in Vilasini et al. (2012)) but, due to high complexity and implementation cost of such arrangements (Hoban and Francis 2003), in practice, most alliance arrangements are between clients and contractors and exclude suppliers (Vilasini et al. 2012). Occasionally, unofficial alliances are created in the form of clans. Clan relationships are connected to economies of familiarity, are encouraged by lack of bureaucracy and the dominance of craft administration, and are subjected to market tests through competitive bidding (Reve and Levitt 1984). Despite the obvious benefits connected to the use of such relational management types, there are also problems abundant in their application. There is embedded mistrust in the organisational culture of construction companies and, SMEs in particular, view partnering related practices as mechanisms contractors use to drive down supplier profits (Dainty, Briscoe and Millett 2001). Other organisational factors that pose problems to relational practices are listed by Storey et al. (2005) as: lack of commitment, diverging corporate strategies and priorities, and differences in levels of trust and commitment at the operational and strategic levels in the organisation. The cost-intensive and time consuming nature of these relationships are another hindrance to their application (Lee et al. 2009). Problems exist even after the adoption barriers have been overcome. For example, supplier schedules are usually integrated only at the contractor's master level making coordination and integration a difficult task (Brown et al. 2001). Information is not shared in a timely and efficient manner (Titus and Bröchner 2005, Doloi 2009) and inability to resolve coordination problems hinders the work progress at the work site (Abdul Kadir et al. 2005).

Despite the problems related to partnering and alliancing, both practices have integration at their core. Integration improves productivity in supply chain collaborations (Kumaraswamy, Anvuur and Smyth 2010). The development of ICT technologies provides organisations with the ability to facilitate relationship management through their consistent and effective use

(Pala et al. 2013). Back in 1998, Kornelius and Wamelink proposed the use of information systems to assist the handling of the massive amount of construction project documents. Currently, construction companies use such systems internally, at the later stages of a project, for the purpose of logistical and inventory management, cost accounting, customer/supplier relationship management, and assessing performance of suppliers (Benton and McHenry 2010). Contractors prefer to use these systems near the end of the project out of fear that the transparency provided by them could increase supplier bargaining power (Vilasini et al. 2012). This means that the use of IT systems for supplier relationship management is reactive in nature instead of proactive (Pala et al. 2013). BIM software is on the rise and is becoming all the more popular amongst contractors. Research conducted by van Lith et al. (2015) showed that contractors who adopted BIM where examining methods to increase supplier involvement in the operational and value creation process through this type of software. They also found that BIM is perceived to improve communication, design and management of processes at the interface of contractor and suppliers relationships, a find that points towards increased maturity in this domain.

There are some process models available in the literature related to supplier management processes, but they mainly focus on the purchasing function. Robinson et al. (1967) described a generic purchasing process comprised of eight stages (anticipation of a client's need; determination of the characteristics and the quantity of the item needed; description of the characteristics and quantity of the item; search for and qualification of potential sources; acquisition and analysis of proposals; evaluation of proposals and selection of suppliers; selection of an order routine; performance feedback and evaluation) that mainly focused on a manufacturing firm's activities. Webster and Wind (1972) described a process that focused on the sequence of decisions (identification of need; establishing specification and scheduling the purchase; identifying purchasing alternatives; evaluating alternative purchasing actions; selecting the suppliers) related to a generic purchasing function. van Weele (2009) proposed a shorter purchasing process based on the work of Robinson et al. (1967) comprised of five stages (specification; selecting the supplier; negotiation and contracting; issuing the contract or order; following up to secure delivery). These models focus on a generic process that does not consider the construction industry's particularities. The most extensive supplier relationship management process available is provided by Lambert and Schwieterman (2012), but despite the generic nature of the model it still focuses on the manufacturing industry. De Boer et al. (2001) performed a review of purchasing decisions in the construction industry and came up with a four stage process (problem definition; formulation of criteria; qualification; choice). Bildsten and Manley (2015) reviewed different purchasing situations in the construction industry and after reviewing the available literature proposed an eight stage process (identifying the need; establishing the specification and scheduling the purchase; identifying purchasing alternatives; evaluating alternative purchasing actions; selecting the supplier; negotiation and contracting; issuing the contract or order; following up to secure delivery) for purchasing in construction. Cheng et al. (2010) used SCOR and BPMN to describe the interactions between project parties during the purchase of a stocked good. Pala et al. (2013) described the management techniques related to supplier relationships contractors used in extended supply chains, but did not present any particular process. Finally, van Lith et al. (2015) presented two processes, a strategic comprised of eight stages (insourcing or outsourcing; develop commodity/product group strategies; optimising supply base; establish and manage strategic relations; integrate suppliers into the value creation process; integrate suppliers into the operational process; improving supplier performance and guarding/developing quality; manage costs strategically across the supply chain) and an operational comprised of six enabling tasks (establish integrated and aligned procurement and supply chain plans and strategies; developing the purchase organisation; utilising supplier market possibilities; performance indicators for purchasing; information technology for purchasing; human resource management). None of the models described focus on the entire range of supplier relationship management processes and have a narrow perspective of upstream supply chain relationships.

4.5.2. Supplier relationship management process model

The "Supplier relationship management" (**Figure 46**) function is the fourth management function in the model and includes all the processes related with supplier selection, management, grouping, tendering, purchasing and negotiation. Supplier relationship management is a critical supply chain management function, as seen in the preceded analysis. A streamlined supplier relationship management function can provide the contractor with a stable and efficient material, information and capital flow (Gou, Liu and Li 2011). Contractors must optimise their supply base in terms of number and quality of suppliers, increase attention paid to their portfolio of suppliers, select the level supplier integration in their processes, and monitor the performance of their suppliers (Bemelmans et al. 2012). The processes in the function must be flexible enough to adapt to the materials management requirements of the entire project portfolio (Safa et al. 2014). The Supplier relationship management function is comprised of eleven processes; three strategic and eight operational. Previous works that have adopted this approach to processes include Lambert and Schwieterman (2012), Pala et al. (2013) and van Lith et al. (2015). Strategic processes aim to provide guidelines for the effective management of suppliers and are the following: "Determine criteria for supplier grouping", "Develop guidelines for the level of flexibility in the project/service agreement", and "Develop guidelines for transfer of benefits from process improvement to the suppliers". Strategic processes can be executed whenever required and with no specific order. Operational processes deal with day to day interaction with suppliers and are the following: "Group suppliers", "Prepare supplier account management teams", "Review supplier accounts and identify opportunities", "Perform supplier tender", "Supplier selection and purchasing", "Negotiate supplier project/service agreements", "Practice supplier project/service agreements", and "Supplier relationship management performance measurement". The first five processes are executed before the contract for a new project is signed and the following two are executed after there is a signed contract with the client. The last process can be executed after the seven previous processes or in parallel to each of them. As with Client relationship management, the importance of such a model can be seen through the following claim by Rowlinson (2005): "*Relationship management is more than a characteristic of project management; it is one of its key features upon which the successful accomplishment of the project is likely to depend*".

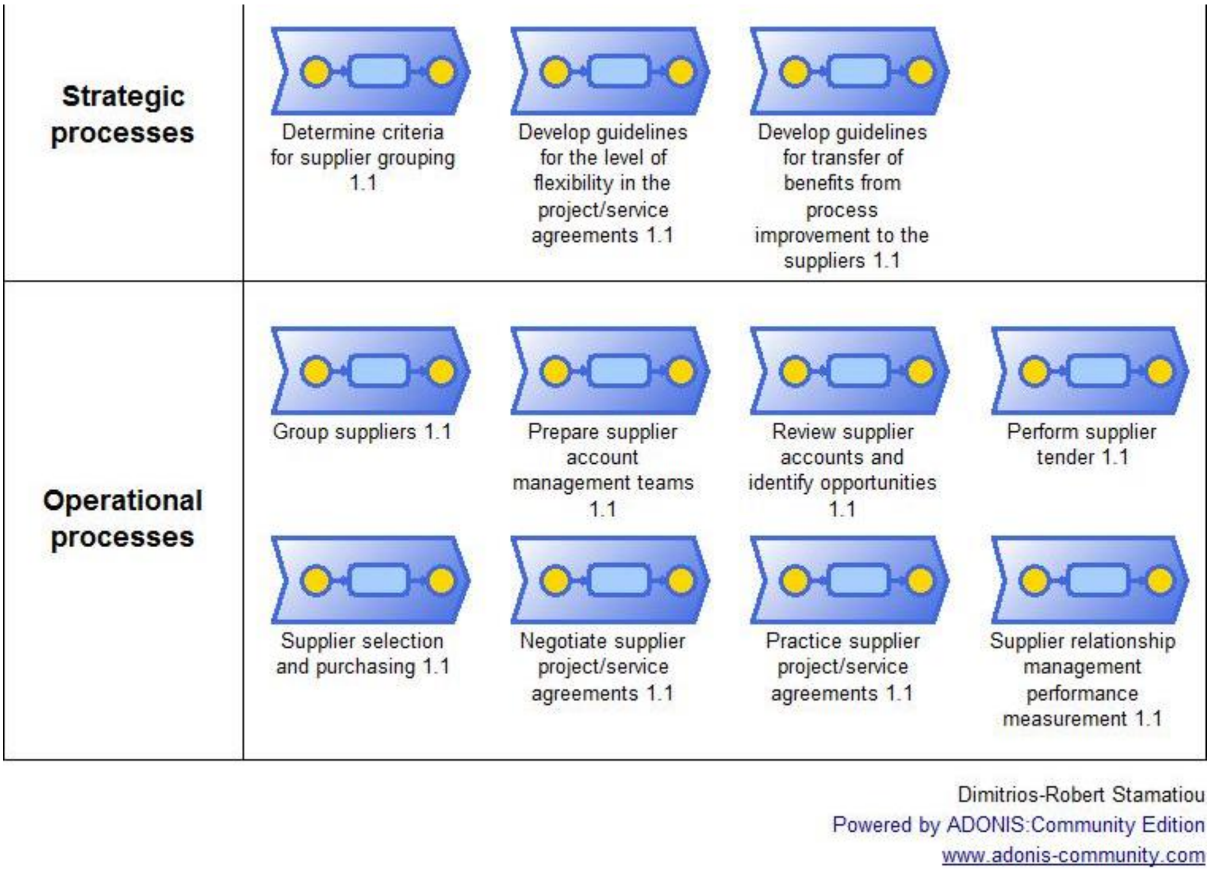

Figure 46: Supplier relationship management function

4.5.2.1. Strategic processes

The first strategic process is "Determine criteria for supplier grouping" as seen in **Figure 47**. This is a very important process since it dictates how supply chain relationships supplement supplier selection strategies (Pala et al. 2013). Furthermore, it provides the required guidelines for optimising the supply base. Suppliers differ in terms of quality, delivery, services, personal interaction, 'know-how' and joint product development (Ulaga and Eggert 2006). Contractors must select suppliers that are constantly at the top of their market and this requires careful analysis and evaluation (Benton and McHenry 2010). The first task is to 'Determine criteria for supplier categorisation'. There are many criteria available to use in order to evaluate suppliers. Some of the criteria for supplier categorisation that were met in the literature can be seen in **Table 14**. Meng (2010), in particular, not only provides criteria, he also presents specific sub-criteria for each criterion. These criteria are used as input to the next task, namely 'Determine supplier categories'. The categorisation of suppliers increases the effectiveness of the purchasing processes by better allocating management capacity, administrative manpower, time and finance required for each relationship (Bildsten 2014). The literature is rich with supplier categories as seen in **Table 15**.

Table 14: Supplier categorisation criteria

Authors	Criteria	
Dyer et al. (1998)	More or less critical to contractors' operations	
Kawa and Koczkodaj (2015)	Supplier reliability	
Ng and Skitmore (2014)	workmanship, progress, safety, environment, relationship, resource control, attitude to claims, communication, promptness of payment, general obligations	
van Lith et al. (2015)	BIM readiness	
Hartmann and Caerteling (2010)	Quality, technical know-how, price, cooperation	
Lambert and Schwieterman (2012)	Profitability/growth/stability, technology, capacity, innovation, quality, volume purchased, criticality/service level required, sophistication/compatibility, sustainability, supply risk	
Meng (2010)	Procurement	Selection criteria, procurement route, form of contract
	Objectives	Objectives alignment, benefits, continuity of work
	Trust	Type of trust, confidence, monitoring others' work
	Collaboration	Working relationship, culture, mutual help
	Communication	Information exchange, Sharing learning and innovation, Cost data transparency
	Problem solving	Early warning, Effectiveness of problem solving, Avoidance of recurrence
	Risk allocation	Risk sharing, Allocation principle, Balance of risk and reward
	Continuous improvement	Joint effort, Measurement and feedback, Incentive mechanism

Table 15: Supplier categories

Authors	Supplier categories
Laryea (2009)	Based on selection mode: nominated, named and domestic
Ohnuma et al. (2000)	Subcontractors of basic activities, subcontractors of technical specialties, labour or materials subcontracting specialties
Lehtinen ((2001) as seen in Vilasini et al. (2012))	By capability profile: critical, strategic, marginal, leverage
Tam et al. (2007)	By functional participation: labour, material, land, machinery, (mixed supply, fix operative of hired machinery)
Ramus et al. (2006)	By payment method: fixed price, schedule of rates, cost plus
	By nature of work: work, supply, service
Bemelmans, Voordijk, Vos, et al. (2012)	supplier, preferred supplier, co-maker, or partner
Kraljic (1983)	By position on profit/risk matrix: supplier of strategic, bottleneck, leverage, or noncritical items/services

The Strategic Forum for Construction (2003) adapted categories of the Kraljic model to match construction industry terminology as follows: process, assurance of supply, leverage, and partnership. The next task, 'Determine supplier category priorities', aims to provide guidelines on how to manage each supplier category by prioritising specific aspects. The utility of this task was described by Greenwood and Yates (2006) as determining the type of relationship governance through the interplay between the environment and human factors. Principles of utility modelling that considers the inter-organisational degree of trust, the relationship time span, the required materials/service specification, and each organisation's delivery demands are used in order to define priorities (Nicholas and Edwards 2003). Contractors have to keep in mind that, in some cases, "*the benefits of secure supply and established routines outweigh the sacrifice of chasing good deals"* (Bildsten 2014) and that value-in-production is generated through long-term relationships. Finally, the task 'Determine contracting strategy for each supplier category' aims to provide the guidelines for operational processes to manage suppliers according to their importance in projects. On the one hand, certain products and services require higher interaction levels than others leading to closer relationships (Bildsten 2014). Contractors must keep in mind that high levels of coordination, trust, information sharing, creativity, and senior management support are required in order to create and fully exploit successful relationships with strategic suppliers (Bemelmans et al. 2012). On the other hand, routine products may be abundant but their low value may not allow for frequent searches for new suppliers (De Boer, Labro and Morlacchi 2001). Robeiro and Love (2003) proposed that for most relationships described in the second case, the adoption of an e-business strategy can add value to the search process.

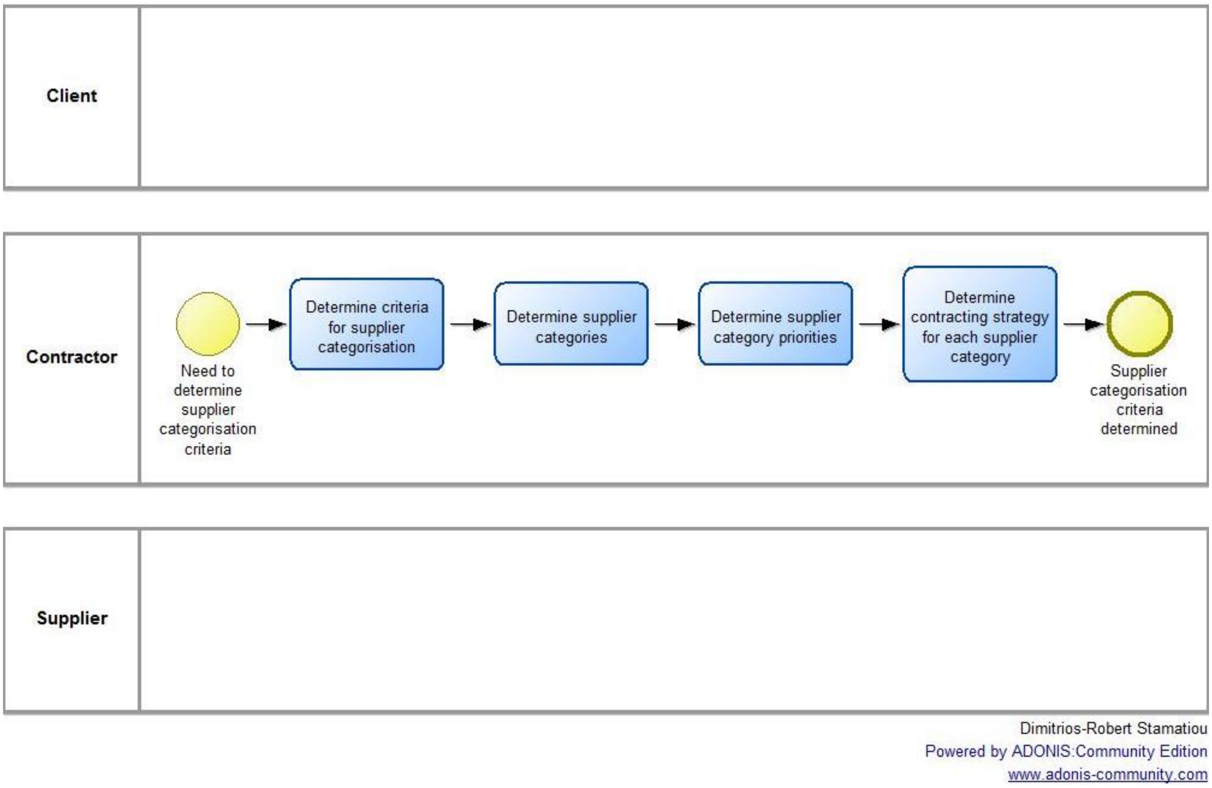

Figure 47: Determine criteria for supplier grouping

The second strategic process is "Develop guidelines for the level of flexibility in the project/service agreement" as seen in **Figure 48**. The first task is to 'Analyse supplier categories' and includes attaining information and evaluation of the potential suppliers. The next task is to 'Assess parameters affecting project agreements with suppliers'. Parameters such as management styles, control systems, quality philosophies, and technological abilities should be evaluated in order to assure good communication during the project (Benton and McHenry 2010). In addition, in some cases, client contracts may provide some assessment parameters for the selection of suppliers. The 'Examine cost-profit fraction for each supplier' task includes the analysis of contract types and their cost/profit levels. Next, the 'Determine guidelines for agreements with suppliers' task aims at providing a set of guidelines for contracts with existing or potential suppliers and management of existing contracts. Finally, it is advisable to 'Develop alternative options for achieving project differentiation agreements with suppliers' in case of extremely specialised suppliers or supplier agreements. It is important to consider any quality/cost implications and set the boundaries of each differentiation alternative (Lambert and Schwieterman 2012).

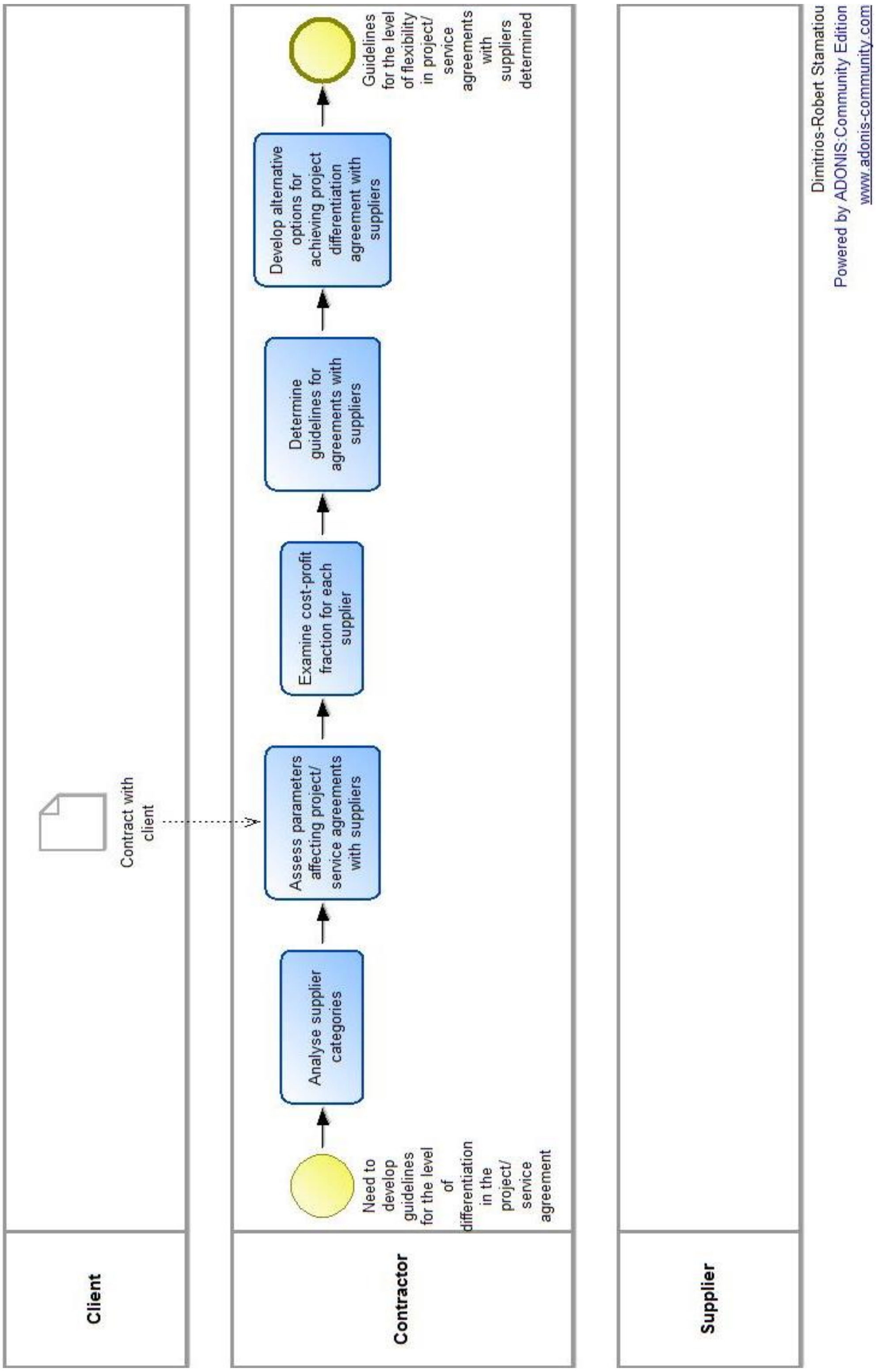

Figure 48: Develop guidelines for the level of flexibility in the project/service agreement

"*A strong recommendation is that construction companies should not only react toward suppliers when something goes wrong, but communicate proactively with suppliers to develop closer and trusting relationships*" (Bemelmans et al. 2012). Following a proactive approach requires that any benefits that occur from improvement in processes or other organisational structures have to be shared with, at least, key suppliers in order to reap even more benefits. This is the aim of the last strategic process; "Develop guidelines for transfer of benefits from process improvement to the suppliers" as seen in **Figure 49**. As with clients, so with suppliers, contractors can benefit from identifying key areas of existing relationships for improvement aiming for performance improvements, reduction of conflicts and opportunities for collaborative working (Meng et al. 2011). The first task of this process is to 'Provide guidelines to recognise possible benefits for the supplier and the organisation' that aims to provide the appropriate guidelines for benefit recognition. Using an organisational approach can lead to elimination of inefficiencies, reduction of costs and improved value (Nicolini, Holti and Smalley 2001). Dainty, Briscoe, et al. (2001) identified that all suppliers must be formally integrated in the project's communication and reporting structure. Next, the task 'Provide guidelines to quantify possible benefits for the supplier and the organisation' is executed with the aim of providing a list of possible tools and methods that can be used to quantify different kinds of benefits. These benefits are usually related to time, cost or quality and can represent the level of cooperation and are usually reaped in future projects (Anvuur and Kumaraswamy 2006). Finally, the 'Develop guidelines to exploit the benefits for both the supplier and the organisation' aims to provide guidelines as to how the proposed benefits can be actualised. Harland (1996) propose the use of the mismatch tool in order to identify and measure gaps in the perception of benefits by both sides.

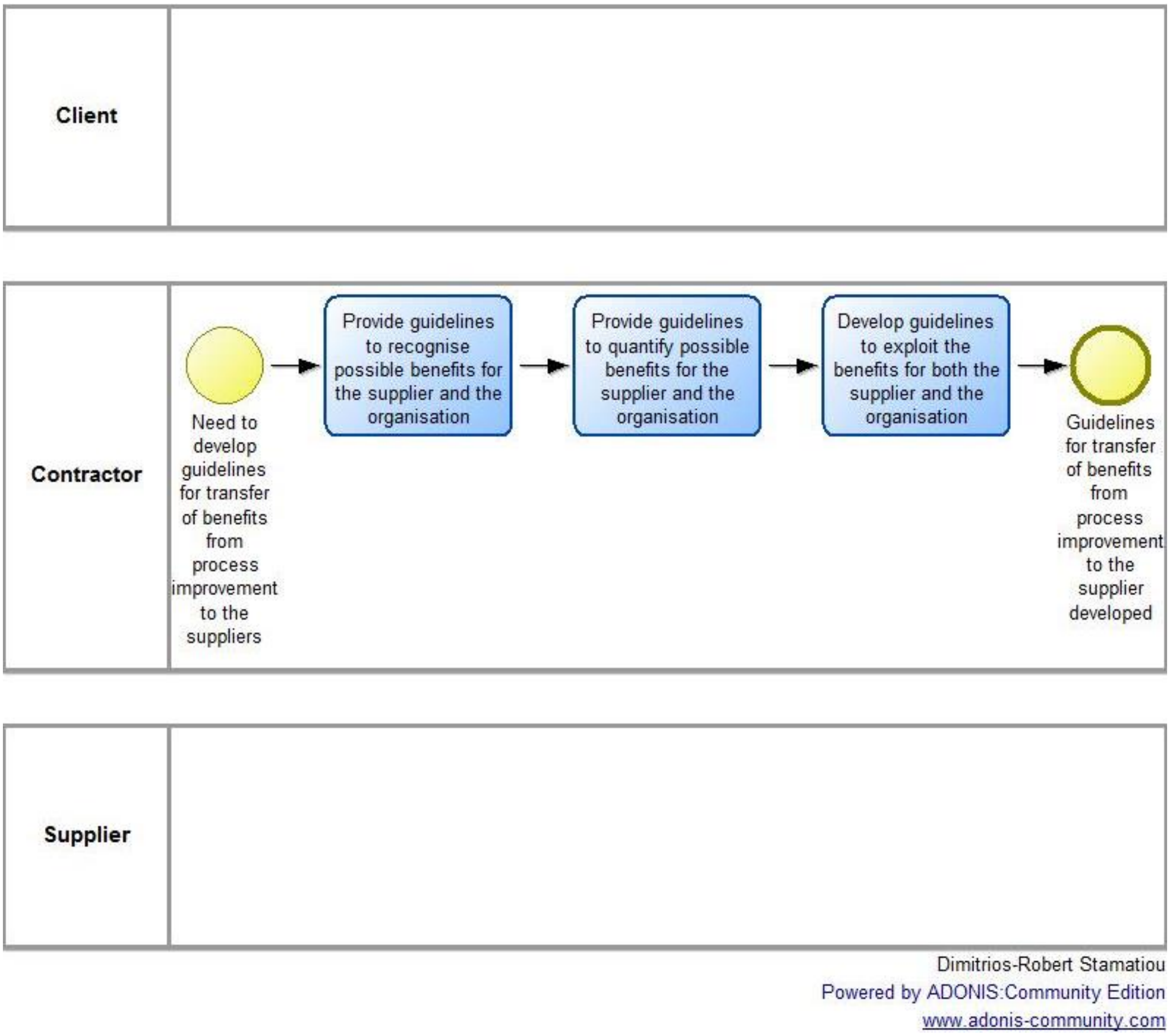

Figure 49: Develop guidelines for transfer of benefits from process improvement to the suppliers

4.5.2.2. Operational processes

The first operational process is “Group suppliers” as seen in **Figure 50**. In large contractors, interviews showed that this grouping may change from project to project depending on the extent of work required by a supplier in a specific project. SME contractors group their suppliers based on price, technical know-how, relationship and project specifications. The first task is to ‘Categorise suppliers based on selected criteria’ based on any of the categorisations seen in the literature (seen in the first strategic process), a combination of these categorisations, or other categorisations developed in the organisation. It is important to determine the correct number and suitability of suppliers in order to optimise the project’s supply base (Bemelmans et al. 2012). Next, the contractor should ‘Analyse supplier profitability’. It important to focus on other aspects beyond price, such as quality, technical know-how, past performance and claims related to the specific supplier when analysing profitability. Not all potential suppliers may add value to the project. The following task, ‘Evaluate potential for future work’, takes into consideration the interplay between past price and trust balance in order to assist future supplier selection processes (Hartmann and Caerteling 2010). Geographical location (Cox and Thompson 1997) and required products and services (Gidado 1996) for each project in the portfolio play part in the potential for future work. Furthermore, previous relationships bear a specific weight in the decision for future work (Manu et al. 2015). Next, the ‘Group suppliers’ task makes use of the data produced in the previous tasks to allocate a supplier in a group that will make its management more efficient. As Bildsten and Manley (2015) point out, this may either be a routine process or a more complex process depending on the criteria selected. Finally, the construction industry environment is extremely volatile and it is important to ‘Determine supplier grouping re-examination period’ in order to be able to follow any changes.

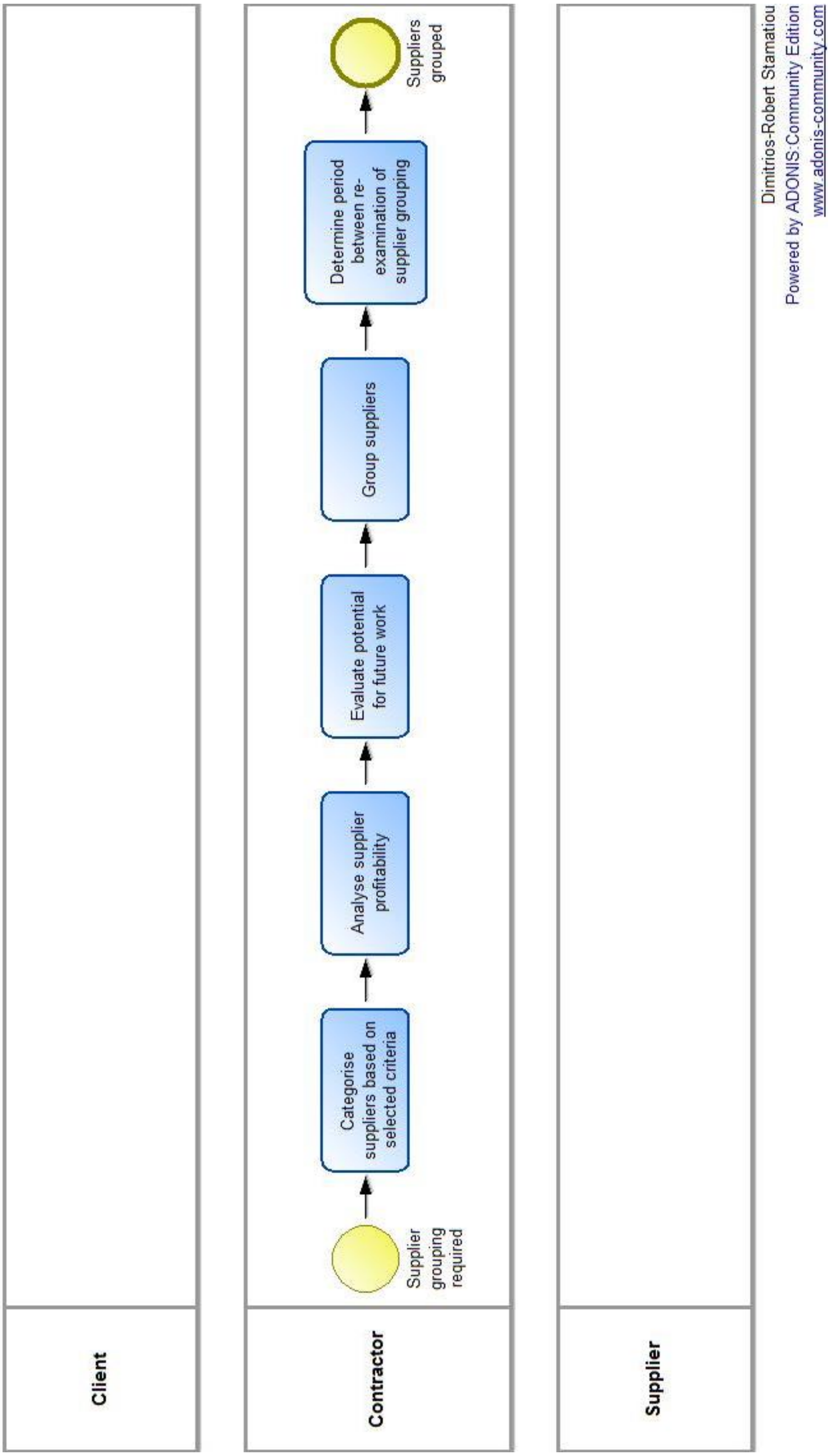

Figure 50: Group suppliers

The second operational process is “Prepare supplier account management teams”, as seen in **Figure 51**. Interviews showed that this process is mainly executed by large contractors that have entire procurement departments managing their suppliers. SME contractors usually lack the funds to maintain such a construct and the head of the company is the one handling supplier relationships singlehandedly. The first task is to ‘Identify supplier behaviour’. It is important to identify if specific suppliers have a past of opportunistic behaviour before deciding to enter a transaction with them. Next, the contractor must ‘Identify supplier contact’, a person or firm that will represent the supplier during the negotiations and, potentially, the project execution phase. Then, the contractor must ‘Select project team leader’. The project team leader is the person that will be making all the important decisions during the negotiation and execution processes and will have the responsibility of the project at hand. Next, based on the project team leader’s suggestions, the contractor must ‘Select supplier management team members’ that will comprise the team that manages the specific supplier and the strategies that are related to the supplier category. Finally, the contractor must ‘Define suppliers' requirements’. It is important to distinguish between governance modes (contract or oral) based on the size of transactions with the supplier (Kamann et al. 2006). Suppliers may require sensitive project information beforehand and this fact calls for written clauses that assure no opportunistic behaviour is conducted by suppliers.

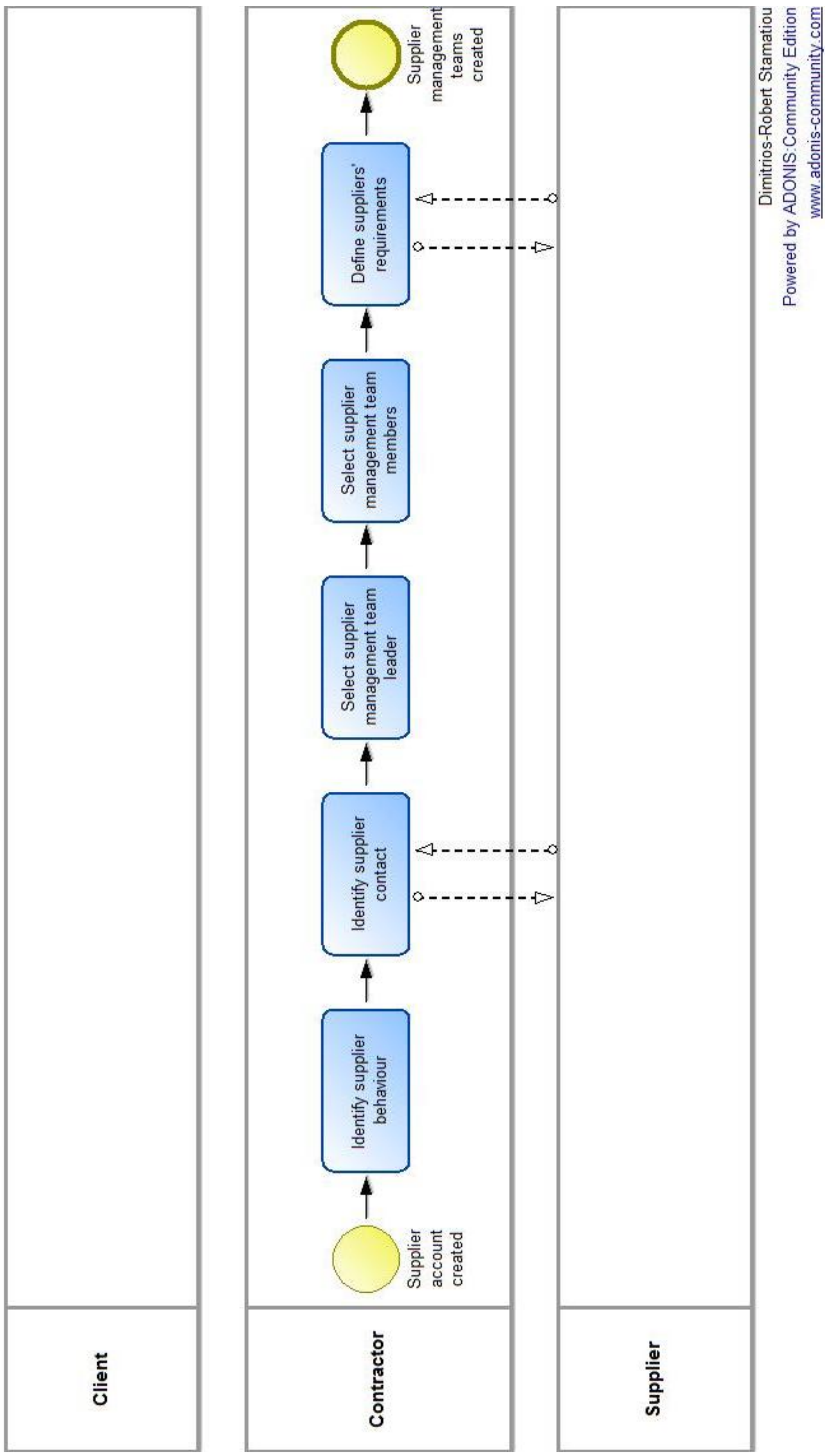

Figure 51: Prepare supplier account management teams

The third operational process is “Review supplier accounts and identify opportunities”, as seen in **Figure 52**. Interviews revealed that this task is mainly executed by large contractors. SME contractors, despite having a shortlist of 3-4 suppliers they trust for each type of work, do not seek to share benefits in the majority of cases. The first task is to ‘Review supplier history’. In the case of a frequent supplier, there should be a history available within the contractor organisation, in other cases clients or other contractors may provide a good source of information. Next, the contractor must ‘Analyse supplier’s market position’. Usually, a smaller supplier has less market power than a large supplier, but there should be an understanding of how the supplier size affects the project in terms of scarcity, specialisation and requirements. It is important to ‘Review supplier’s priorities’ in order to allow the contractor to better understand the supplier’s needs and requirements, along with the possible tolerance to changes. The contractor must communicate with the supplier and ‘Identify cost reduction opportunities’. Changes in prices of stock market goods, wages, or other cost inducing factors may benefit both sides in a synergistic relationship. Such transactions allow trust to be built. Next, the contractor should ‘Identify service improvement opportunities’ that will make operations more efficient in future projects and, finally, ‘Check for tax and tariffs in selected channels’. The existence of unforeseen tax and/or tariffs may increase costs and reduce profit margins and cause delays.

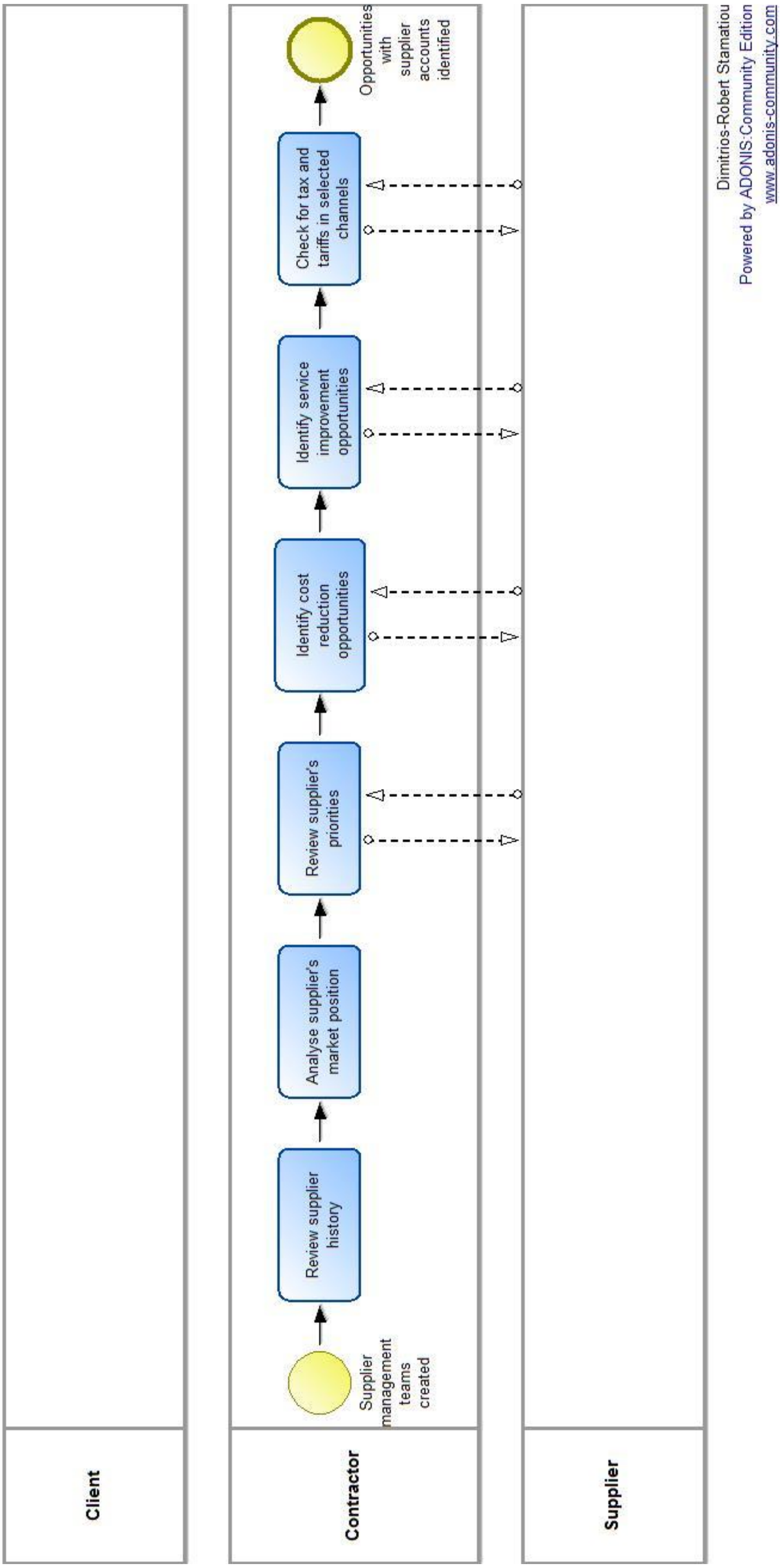

Figure 52: Review supplier accounts and identify opportunities

The fourth operational process is “Perform supplier tender”, as seen in **Figure 53**. The study by Laryea (2009) found that contractors face high expenses and have a lot of space for efficiency improvement in their supplier tender engagements. The first task in the process is to ‘Perform enquiries’. Enquiries are performed by contractors in order to calculate bid prices. Studies by Massey (1992) and Farrow (1993) (as both seen in Laryea (2009)) showed that the number of enquiries performed should depend upon the following: likely response level, volume and criticality of the product/service, volume of the enquiry documentation, and the cost of sending either a large or small number of enquiries. In addition, both enquiries and future bids can be affected by up to 10% by relationships with the suppliers (Shash 1998). Contractors have to provide all related documents to their potential suppliers in order to get a precise quotation. The most important documents related to enquiries are drawings and bill of quantities (Enshassi and Medoukh 2008). Other related details include specifications, materials quantity, delivery date, terms and price conditions, discounts and pro forma, site address and access details, and quotation submission end date (Laryea 2009). The next task is to ‘Select suppliers to invite’. The study by Laryea (2009) concluded that “*contractors should limit their enquiry invitations to a maximum of three per package, and optimise the waiting time for quotations in order to improve cost efficiency*”. This is followed by the ‘Invite suppliers to tender’ task. The invitation should contain the following according to Laryea (2009): the specific nature and extent of work; terms and conditions of the main contract; conditions of the subcontract; details of anticipated staffing and completion dates; services, resources and attendances to be provided by the main contractor; specific requirements relating to method and programme; and quotation due-date. The contractor must make for ample time for the tendering process in case of amendments that may occur on the client’s side (Massey (1992) as seen in Laryea (2009)). In addition, contractors must request their suppliers to accompany their tenders with the following documentation, except price, listed by Enshassi and Medoukh (2008): method of execution, past experience in similar works, time schedule, expected obstruction, and any other special conditions. In case suppliers request it, the contractor must ‘Provide clarifications’. Then, the contractor must ‘Analyse bids’ based on price, technical know-how, quality, communication, delivery, customer service, supplier location, and supplier financial stability criteria (Benton and McHenry 2010, Bemelmans et al. 2012). Finally, the contractor will ‘Qualify suppliers’ that meet the criteria mentioned. Some additional criteria that can be considered here are satisfaction, relationship-specific adaptations, reputation, and loyalty (Sjoerdsma and van Weele 2015). There are many qualification methods mentioned in the literature, for example the linear averaging method (Benton and McHenry 2010) and the multi-criteria decision support model (Schramm and Morais 2012). This will form a pool of suppliers which will be used as input in the next process.

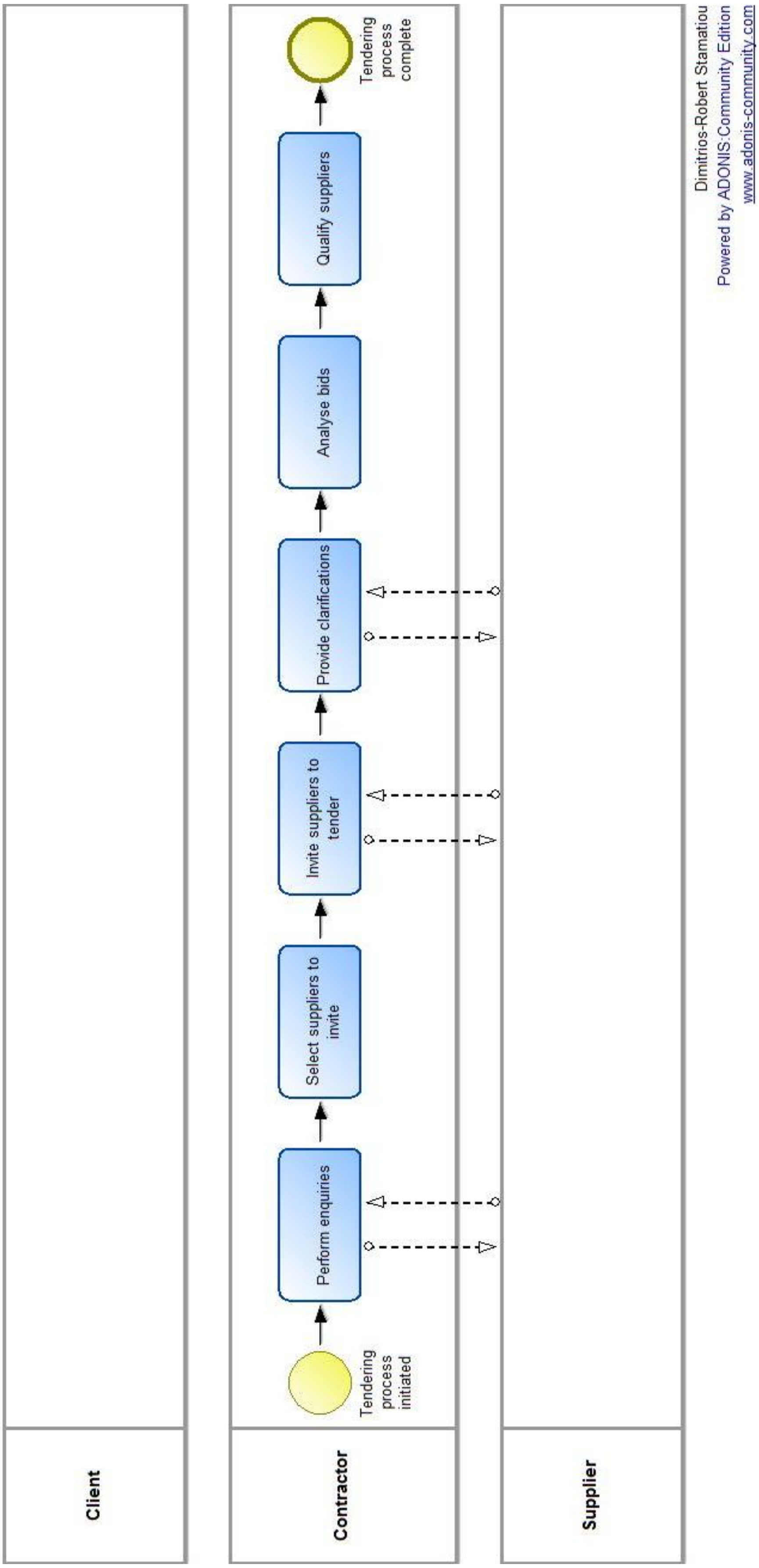

Figure 53: Perform supplier tender

The fifth operational process is “Supplier selection and purchasing”, as seen in **Figure 54**. Potential suppliers have been chosen in the previous process and the purchasing process works with a specified pool of suppliers. The first task is to ‘Define type of buy’. According to Robinson et al. (1967), there are three discrete types of purchases named new-buy, modified rebuy and straight rebuy. In the first case the contractor makes a buy that has never been performed before, in the second case the contractor makes a buy that has smaller or larger differentiations to past ones, and in the third case the contractor repeats an identical buy. It is important to identify the type of buy as there are different levels of complexity to each one (Bildsten and Manley 2015). Next, the contractor must ‘Define purchase interface’. According to Boes and Holmen (2003) there are four purchase interfaces, namely: standardised, specified, translation, and interactive interface. In the first case the contractor buys a standard product/service from the supplier, in the second case the contractor buys a customised product/service from the supplier based on specified technical prescriptions by the contractor, in the third case the contractor buys a customised product/service from the supplier based on the supplier’s understanding of the contractor’s functional specifications, and in the fourth case the contractor buys a customised product/service from the supplier that has been created through an open dialogue and exchange of knowledge between the two sides. This task is important due to the different levels of complexity related to each purchasing interface. Next, the contractor performs the ‘Define volume of purchase’ task. For example, non-project specific items can be used across several projects and thus large purchase volumes may make sense (Bildsten 2014). The number of suppliers available, the importance of the purchase, the importance of the supplier relationship, and the amount and nature of uncertainty are situational factors that affect such a decision (De Boer, Labro and Morlacchi 2001) and the contractor must depend on both his own experience and supplier provided details in order to make the purchase (Daneshgari and Harbin 2004). This makes interaction between the two sides important. Next, the contractor must ‘Select supplier’. In this task the final supplier is selected for a contract negotiation. Usually this decision is made based on the cost-price imperative (Hillebrandt 1985) due to the fact that it minimises costs and risks of costs not covered by the bid (Hartmann and Caerteling 2010). Price, along with delivery time are considered threshold factors for supplier selection (Kawa and Koczkodaj 2015). Contractors must also consider how easy it is to replace the selected supplier in case of unforeseen events that dictate such a need and have alternatives ready (Benton and McHenry 2010). There are many tools to support this decision available in the literature. For example, De Boer et al. (2001) propose the use of operational research (OR) models because of their ability to enhance the effectiveness and efficiency of such decisions. Elsewhere, Kawa and Koczkodaj (2015) propose the use of consistency-driven pairwise comparisons for both tangible and intangible criteria to aid supplier selection. The supplier is notified of their selection and has to respond in acceptance or denial. Finally, the contractor must execute the ‘Schedule purchase’ task in order to initiate the negotiation process. Benton and McHenry (2010) listed the following purchasing mistakes construction companies should be aware of: lack of proficiency in identifying supplier capabilities, convenient rationalisation of supplier decisions, late assessment of supplier value added, inability to recognise impact of economic changes on bulk prices, and inability to follow the supplier market changes.

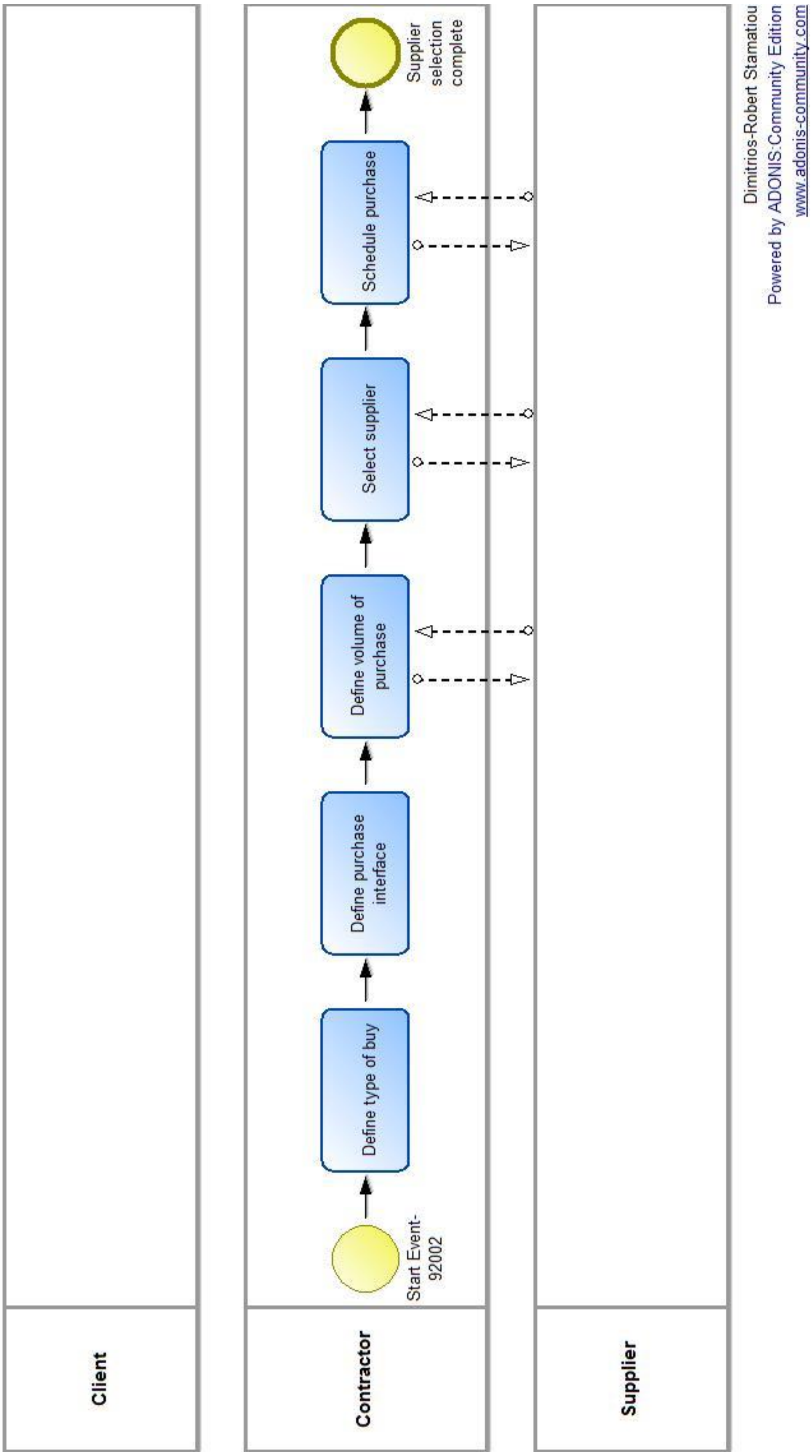

Figure 54: Supplier selection and purchasing

The sixth operational process is “Negotiate supplier project/service agreements” and, as seen in **Figure 55**, describes the contract negotiation process with the supplier. In a negotiation, the factors that contractors are less elastic towards are price and delivery objectives (Schramm and Morais 2012). The first task is to ‘Prepare supplier contract draft’ that should contain all the clauses the contractor is not ready to give up in order for the negotiation process to go on. Next, the contractor should ‘Check supplier contract draft’ in order to make sure all the required fields are in place. It is important to analyse the supplier and determine a negotiation strategy in order to get the most out of the negotiation process, which means that it is important to ‘Determine supplier agreement terms’. The next tasks in the process are ‘Present agreement to supplier’ executed by the contractor, ‘Check agreement’ executed by the supplier and ‘Receive supplier’s reply’ executed by the contractor which outline the actual negotiation. The supplier either accepts the contract (or requests minor changes the contractor can accept) and the ‘Finalise supplier contract’ task is executed, or rejects the contract (or requests major changes) that means the contractor has to ‘Check set strategy for the supplier category’ and depending on the supplier to either ‘Withdraw supplier contract’ or to ‘Develop plan to improve supplier contract’ and start the process from the third task. Interviews revealed that in the case of SME contractors, clients may interfere with supplier negotiations depending on the size of the contract.

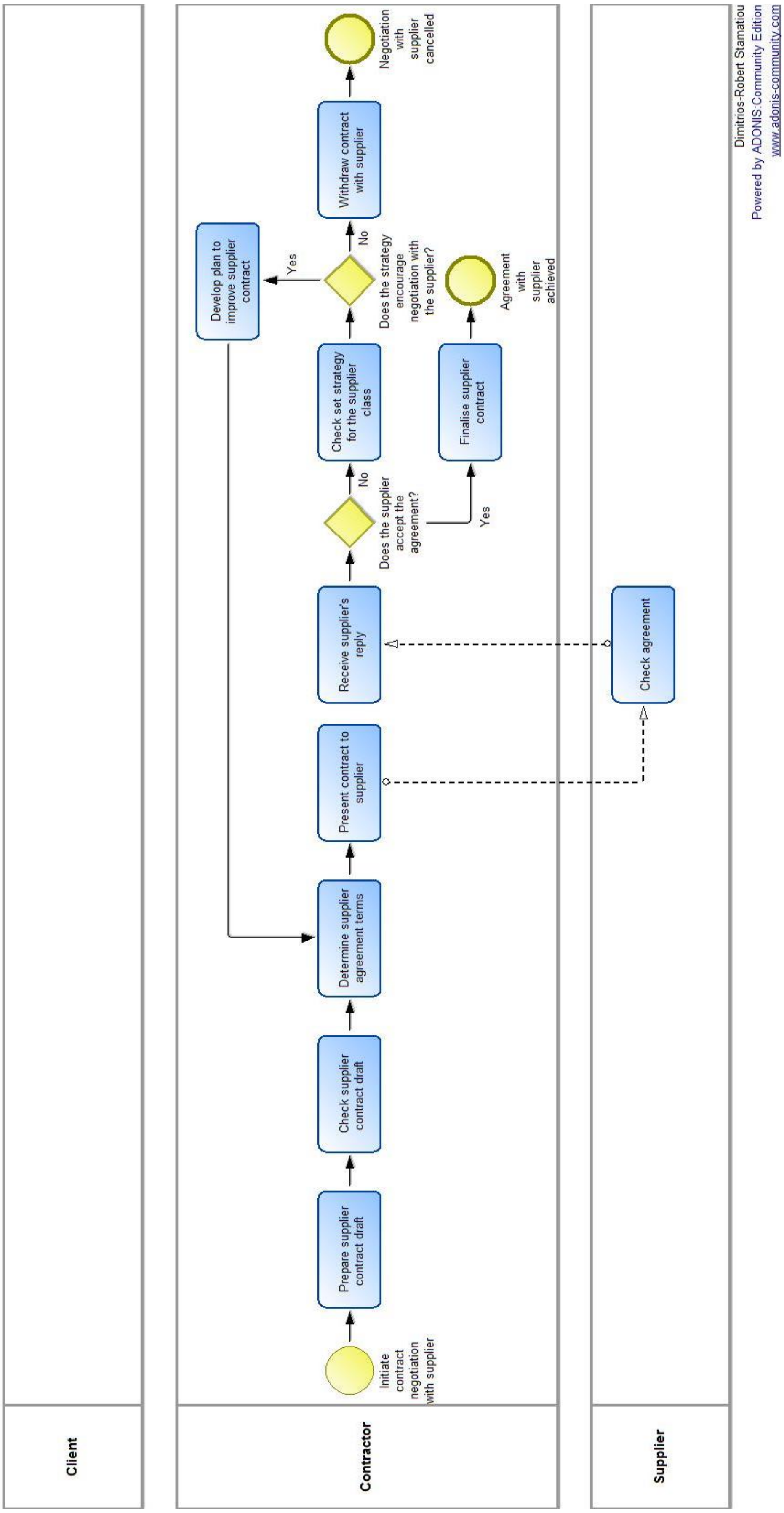

Figure 55: Negotiate supplier project/service agreements

The seventh operational process is "Practice supplier project/service agreements", as seen in **Figure 56**. After the contract has been signed, there are many problems that may occur during its execution. That is why the contractor has to 'Develop implementation plans' that will layout the strategy of communication with the supplier. This is required since each supplier is contractually tied to the contractor while the work flows from one supplier to the next (Karim, Marosszeky and Davis 2006). The contractor must 'Provide supplier with access to project data' so that any discrepancies can be traced on time. Supplier tasks may seem straightforward but require numerous preparation, production and scheduling tasks (Tommelein and Ballard 1997). The next task, 'Perform meetings with supplier', is the main method to keep in contact with the supplier and monitor any changes in requirements. It is important to always keep the supplier up to date with any changes that affect his operations (Mirawati, Othman and Risyawati 2015). Finally, the contractor must 'Re-examine problematic agreement areas' in cooperation with the supplier and, when it is deemed critical, the clients.

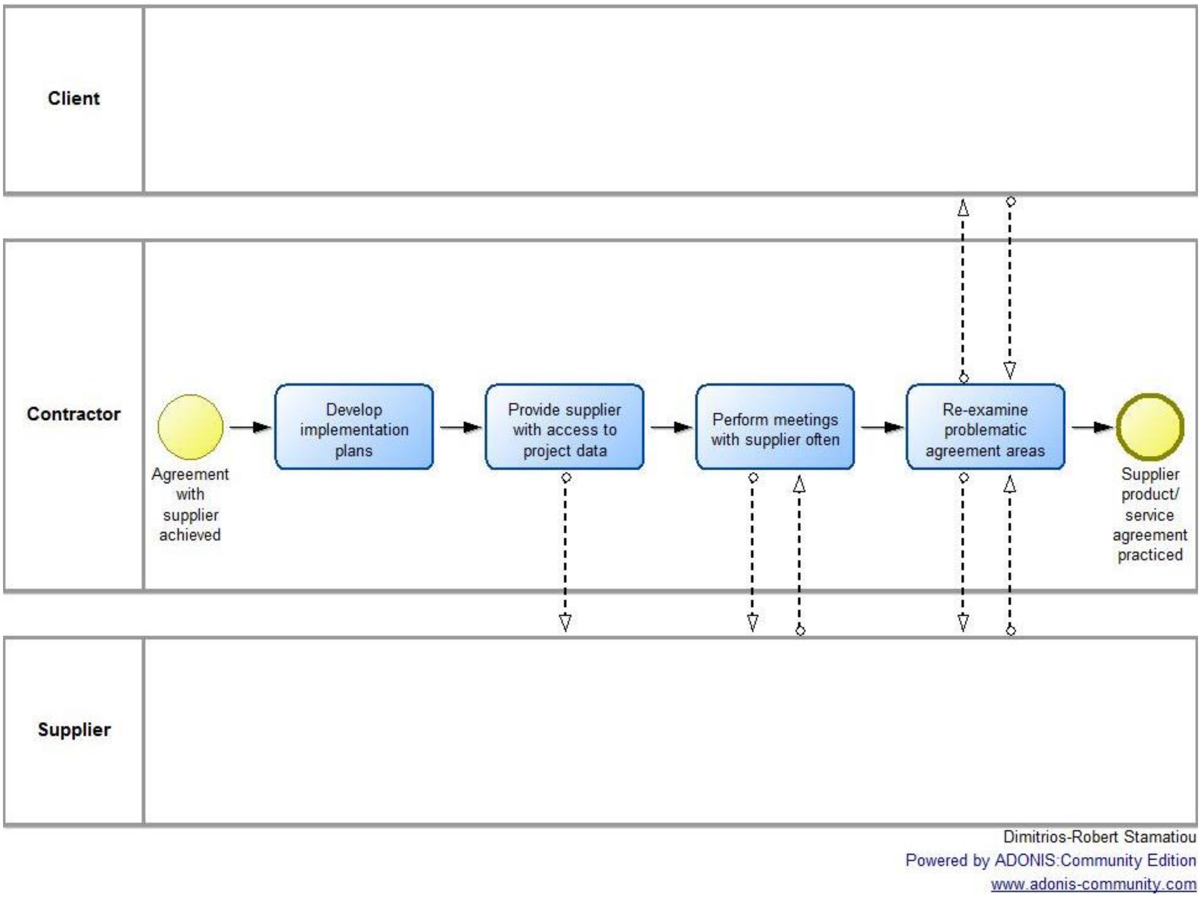

Figure 56: Practice supplier project/service agreements

The last operational process, namely "Supplier relationship management performance measurement", as seen in **Figure 57**, deals with the measurement of supplier relationship management processes and supplier performance. It can be executed for either previous operational process independently or for all of them collectively. The benefits of monitoring a relationship relate to the surfacing of entities such as the supply market, type of commodity, purchasing history, future portfolio expenditure, and performance of supplier within the cost/time/quality criteria that will support future supplier transaction decisions (Pala et al. 2013). In addition, such a process can support both short-term problem resolution and long-term strategic decision making (Karim, Marosszeky and Davis 2006). It also minimises the occurrence of undesirable events (Shiau et al. 2002), evaluates supplier suitability for future projects (Mbachu 2008) and supports the improvement of accuracy and fairness of subcontractor performance appraisal (Ng, Tang and Palaneeswaran 2009, Ng and Tang 2010, Ng and Skitmore 2014). The first task is to ‘Record and classify supplier relationship management process data’ and aims at monitoring process execution and collecting the relative data generated. Data is generated during both the execution and the result of each process and underperforming or overachieving operations can be recognised through this task. **Table 16** lists the supplier relationship management and supplier performance indicators identified in the literature.

Table 16: Performance indicators mentioned in the literature

Authors	Performance indicators
Schramm and Morais (2012)	quality of input, meeting delivery deadline, fulfilling input volume, competitiveness in terms of the price established by the market and quality in services
Meng (2010)	trust, objectives, teamwork, risk allocation, communication, continuous improvement, business attitude, problem solving, procurement system, and senior management commitment
Ng and Skitmore (2014)	workmanship, progress and safety
Bildsten (2014)	cost/price, material flow, abundant supply, decentralised decision authority
Ohnuma et al. (2000)	transaction costs, training, work security, technological innovation, waste, worker’s motivation, waste of production process control, coordination of subcontractors, planning and programming

The task that follows, ‘Monitor supplier relationship management performance indicators’, uses the data collected previously to compare with the performance indicators set at the strategic level. There are many methods to evaluate performance. For example, Benton and McHenry (2010) mention the categorical and cost analysis methods. Next, the ‘Detect main problems in supplier relationship management’ task aims at identifying the major problems that occur in the supplier relationship management processes for each supplier individually and for each supplier group. The contractor should ‘Draft supplier cost and profitability reports’ for each supplier individually and supplier groups based on the financial indicators recorded and aims at identifying the costs and the profitability that have been incurred by the execution of the entire supplier relationship management function, each task and process in particular, and the total supplier list. Finally, the ‘Determine performance improvement objectives’ task is executed. The task aims to capitalise the acquired knowledge for improving performance in future projects. These objectives can be shared with other key parties of the supply chain. As Matthews et al. (1996) point out, failure to involve smaller companies may lead to the failure of performance improvement incentives.

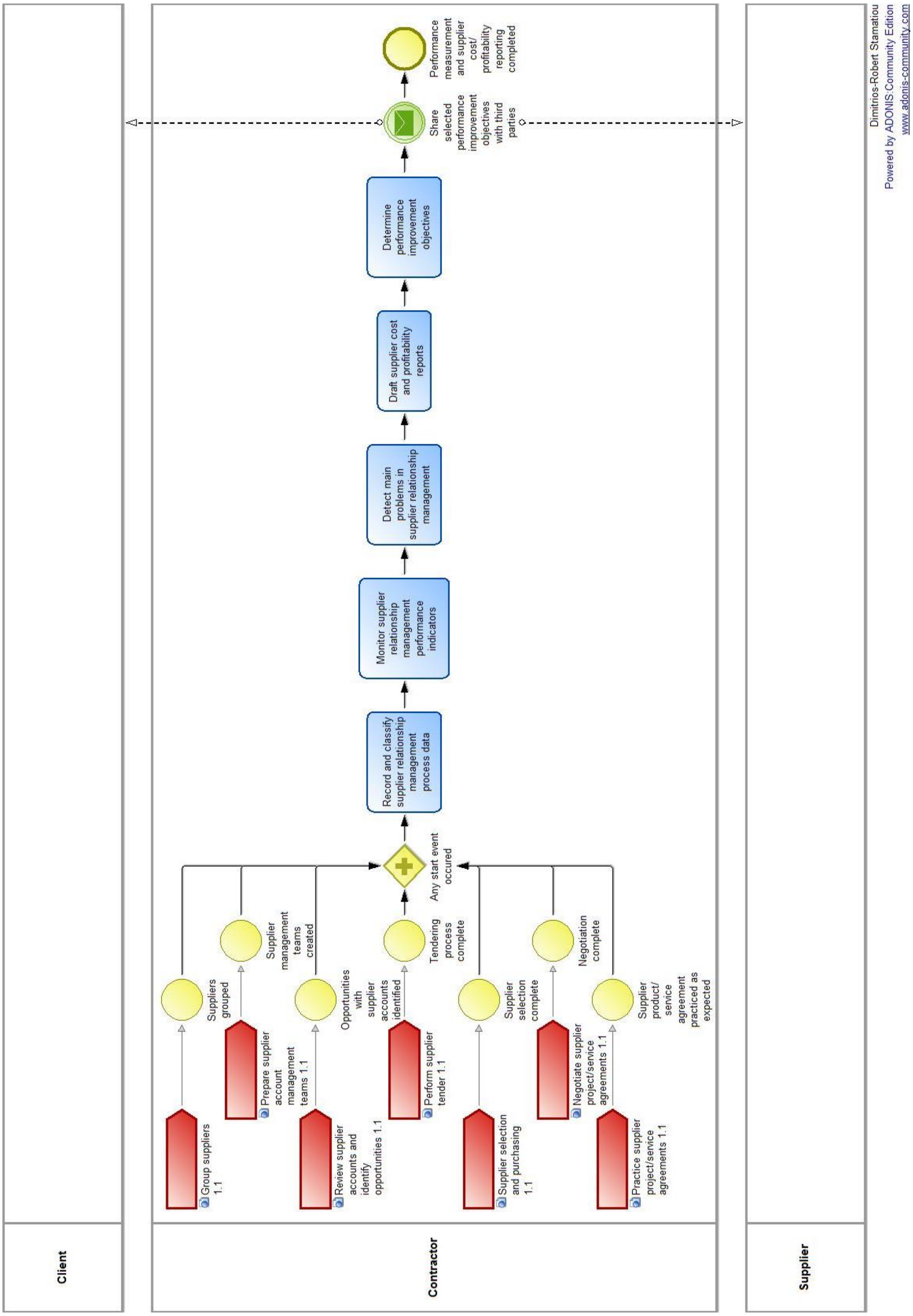

Figure 57: Supplier relationship management performance measurement

4.6. Develop key performance indicator framework

4.6.1. Analysis of key performance indicators development

"*You cannot manage what you cannot measure*" (Sink and Tuttle 1989). Contemporary organisations recognise that improvements to their existing products and processes have the ability to introduce entirely new products with expanded capabilities (Kaplan and Norton 1992). In order to accomplish such improvements, process performance assessment is critical and proper frameworks are required to complete this assessment (Beary and Abdelhamid 2005). Thus, most organisations introduce performance management systems. The introduction of these systems does not always guarantee performance improvement. It is often observed that people manage what gets measured and linked to their performance evaluations (Brewer 2002). This constitutes symptomatic treatment and does not provide predictability, does not define possible branching and actions, does not clearly define areas of responsibility, and only focuses on the most important failures (Kovács 2016). Nonetheless, client endorsement of best practices leads to their implementation (Tennant, Fernie and Murray 2014). Measures provide a basis to evaluate alternatives and identify decision criteria (Abu-suleiman, Boardman and Priest 2004). Modern day businesses use complex management systems that include components of performance management. Performance management includes measurement, analysis and improvement (Suwansaranyu 2002). Performance measurement systems are usually introduced into organisations in order to monitor goal achievement, to allocate resources and to implement a strategy (Franceschini, Galetto and Turina 2014). Kaplan and Norton (1992) identified that traditional financial accounting measures (e.g. return-on-investment, earnings-per-share) can give misleading signals for continuous improvement and innovation. Chan and Qi (2003) point out that "*performance measurement goes well beyond just quantification and accounting*". One of the main concerns in performance management is to find the 'right' indicators for monitoring a given process or system (Franceschini, Galetto and Turina 2014). The importance of process improvement is a derivative of the widely accepted Total Quality Management principle that dictates that the quality of a product/service is largely determined by the quality of the process used to develop it and maintain it. Thus, improving processes can improve an organisation's business (Coletta 2011). The truth is that due to the finite nature of organisational resources, they are pressed to prioritise their efforts and identify those areas where positive effects of are most likely (Oliveira, McCormack and Trkman 2012). Beary and Abdelhamid (2005) highlighted the need to develop a performance measurement system for all processes that affect the execution of construction projects. In construction a major theme is project success. Success on a project means that certain expectations for a given participant were met, whether owner, planner, engineer, contractor, or operator (Sanvido et al. 1992). The literature offers a few frameworks for business performance measurement. More specifically, the supply chain management related literature has two prominent frameworks: SCOR (The Supply Chain Council 2010) and balanced scorecard (Kaplan and Norton 1992). Both frameworks have been utilised by academics to measure the performance of construction supply chains or to provide performance measurement tools (e.g Persson, Bengtsson and Gustad, 2010; Halman and Voordijk, 2012; Thunberg and Persson, 2014).

Performance management has become an increasingly important and integral part of contemporary organisational management. Modern organisations have to understand that performance measurement goes well beyond quantification and accounting (Chan and Qi

2003). All organisations use some kind of measurement tool, be it just a few basic financial indicators or be it a complex system of metrics that covers all operations through the assistance of IT systems. Performance measurement is a top-down methodology that translates strategy into key measures. The bottom-up approach is called Business Analytics and tries to use available data to make meaning. The use of business analytics can have a profound influence on performance at operational, tactical and even strategic levels (Popovič, Coelho and Jaklič 2009). The use of both approaches provides the best results. Suwansaranyu (2002) describes performance management as a closed loop of three discrete phases; measurement, analysis, and improvement. Information acquired in measurement is used as input for analysis. Analysis entails the comparison of measurements to targets set. This analysis leads to improvement through decision making, and after improvement has been defined the cycle leads back to the measurement step. Performance indicators are the main tool for measurement. Franceschini et al. (2014) support that: "*the definition of indicator is strictly connected to the notion of representation-target*". They describe a representation-target as the operation aiming to make a context 'tangible' for evaluations, comparisons, predictions and decisions, and indicators as the vehicle to this transformation. Organisations aim at profit and it is only natural that they rely on financial indicators to monitor their performance. Kaplan and Norton (1992) state that "*financial indicators have received criticism for their well-documented inadequacies, their backward-looking focus, and their inability to reflect contemporary value creating actions"*. Ideally, organisations should give basis to indicators related to quality, production times, delivery, and new product introduction. This means that in many cases new indicators or even new measurement systems have to be introduced. In the first case, there are many elements to be considered before introducing new indicators. Franceschini et al. (2014) highlight the following: system maturity; organisational size; organisational structure; organisational culture; resources; information systems; management style; alignment with objectives; interpretation and evaluation, communication, and information provision; performance measurement system content; and structure and presentation. In the second case, many organisations with systems already in place to collect data and process information find themselves in a situation where they have no roadmaps to put their vast data and information into use (Ranjan 2008). Contemporary organisations exist in a highly competitive globalised system. Therefore, their measurement systems should be able to signal a potential problem in advance rather than report after it occurs (Suwansaranyu 2002). Gunasekaran et al. (2001) identified the following reasons to study the measures and metrics: lack of a balanced approach, lack of understanding on deciding on the number of metrics to be used, and lack of clear distinction between metrics at strategic, tactical, and operational levels. Indicators may simply be used to monitor a specific process or explicitly introduced to enhance its performance, in any case though they act as conceptual technologies embedding normative assumptions and influencing the behaviour of organisations (Barnetson and Cutright 2000). Indicators should be aligned with strategy and define areas of organisational improvement (Abu-suleiman, Boardman and Priest 2004). One of the most impactful improvement areas within an organisation is its processes. Davenport (2006) underlines that most firms offer similar products and use comparable technologies, making business processes one of the last remaining points of differentiation with business analytics optimising their value.

Another point of differentiation for organisations is the supply chain (Hofmann, Beck and Füger 2013). Business activities, such as supply chain management which has strategic implications for any company, identifying the required performance measures on most of the criteria is essential and should be an integral part of any business strategy (Rajat Bhagwat & Sharma 2007). Supply chain performance measurement becomes extremely important in contemporary competitive markets. Measurement of supply chain processes allow for monitoring of the performance of single companies and supply chains as a whole (Oliveira, McCormack and Trkman 2012). Actively tracking key supply chain metrics for management purposes is a necessary component of an internally integrated supply chain organisation (Jenkins, Ibarra and Roussel 2001). One has to identify supply chain processes in order to define and assign metrics based on the analysis of the identified processes. There are two advantages to a process-based model approach (Abu-suleiman, Boardman and Priest 2004): promoting global optimisation by considering the totality of the process, and enabling effective metric selection process by addressing process specific performance. Monitoring and improving the performance of a supply chain has increased in complexity and includes many management processes such as identifying measures, defining targets, planning, communication, monitoring, reporting and feedback (Cai et al. 2009). Supply chain management strategy on its own is a weak predictor of supply chain management performance (Sukati et al. 2012). Supply chain analytics are an important topic since enhancing effectiveness and efficiency of these analytics is a critical component of a chain's ability to achieve its competitive advantage (Sahay and Ranjan 2008). Exploiting information to improve organisational processes and/or their outcomes is central to most supply chain management activities (Hult, Ketchen and Slater 2004). Leaders recognise that supply chain performance management is critical to extracting value from the supply chain (Jenkins, Ibarra and Roussel 2001). Supply chain management is a strategic key to improve operational performance, and facilitates achieving its organisational goals (Abu-suleiman, Boardman and Priest 2004). At a more basic level, performance management enables the improvement and better management of operations (Jenkins, Ibarra and Roussel 2001). Such improvements could ultimately be passed directly to good debtors in terms of lower materials costs, better delivery specifications, and improved creditor staff motivation (Nicholas and Edwards 2003). This enhances cooperation and partnership development at a supply chain level.

The construction industry, as discussed previously, is very different to the manufacturing industry. Construction supply chains often do not have a standard and well-structured configuration and members may not be involved in both the material flows and the information flows (Cheng et al. 2010). Its project based nature means that learning and feedback loops are often broken (Halman and Voordijk 2012). Current applicable literature focuses mainly on assessing the main contractor’s ability to construct a building according to customer requirements and the literature considering the measurement of supplier and subcontractor performance is very limited (Thunberg and Persson 2014). Construction performance is mainly monitored at a national level through government reports (e.g. Glenigan et al. 2011). Sarshar et al. (2000) proposed that one method of increasing predictability and delivering increased customer value is through the systematic management of construction processes. Cheng et al. (2010) identified many areas for improvement in construction organisations, namely, process re-engineering, suppliers’ inventory management, collaboration, trust building, communication, organisational structure and e-business deployment. Process improvement has been identified as an important strategy to address the current unpredictability and under-achievements of the UK construction industry (Keraminiyage, Amaratunga and Haigh 2005). Roy et al. (2005)

identified a lack of process documentation and even standards in construction organisations that does not encourage process review and impedes the dissemination of new knowledge and innovation. Cheng et al. (2010) support that the lack of mapping and measuring the entire supply chain from supplier to customer in the construction industry leads to inability to identify bottlenecks and deficiencies to rectify. Thunberg and Persson (2014) state that "*Omitting supplier performance when evaluating construction performance reduces the ability to improve the construction supply chain, as reasons for cost and time overruns and quality deficiencies will often be overlooked*". Flow is harder to measure in construction. The status of work locations must be monitored (Bertelsen and Sacks 2007) because the work crews move while the products are stationary (Sacks et al. 2017). The craft-based approach to construction, however, makes process control difficult, and the shortage of well-trained workforce has exacerbated the situation (Roy, Low and Waller 2005). Halman and Voordijk (2012) highlight that in the external business process perspective, the level of improvement of sourcing leadership is measured by focusing on the quality of purchased goods delivered on the construction site and the quality of delivery, collaboration with partners and the purchase order transaction efficiency. The improvement of these skills depends on the process maturity of construction organisations. Sarshar et al. (2000) identified that in an immature organisation, construction processes are generally improvised by practitioners and project managers during the course of the project, whereas, in a mature construction organisation an organisation-wide ability for managing design, construction and maintenance activities already exists.

Processes do not exist in isolation; they interact with each other in a network. This interaction may be through exchange of work products, provision of support or provision of organisational infrastructure for the establishment, and improvement of processes in general (Coletta 2011). There are many process improvement models in the literature, the most popular being: the management process model (Kurstedt 1985, as seen in Suwansaranyu 2002), the management process (Kaydos 1991), and the Plan-Do-Check-Act cycle (Deming 1986). The last one is the basis for management system standards such as ISO 9001, ISO 14001, ISO/IEC 27001 and ISO/IEC 20000-1 (Coletta 2011). Cheng et al. (2010) identified that standard methods or frameworks for representing and modelling supply chain structures are few. Furthermore, Willis and Rankin (2012) realise that most process management initiatives have led to the development and use of performance measurement frameworks and models focusing on the organisational and project levels. The supply chain management literature has two predominant performance management models to showcase: SCOR (The Supply Chain Council 2010) and the Balanced Scorecard (Kaplan and Norton 1992). SCOR is a process reference model widely accepted in literature. Ntabe et al. (2014) and Camargo et al. (2013) identified more than forty applications of SCOR in academic literature during a ten year period. This wide acceptance and implementation gives it critical mass, converging on a de facto standard for supply chain measurement (Gulledge and Chavusholu 2008). SCOR prescribes five basic processes (Plan, Source, Make, Deliver, Return) implemented in four distinct levels. The three top levels describe standardised elements of the model and the fourth allows for a connection to the existing company processes. SCOR, from a process perspective, has been developed to facilitate the construction of a systematic supply chain performance measurement and improvement tool and is often recognised as a systematic approach for identifying, evaluating and monitoring supply chain performance (Cai et al. 2009). Furthermore, it has evolved to provide a common supply chain framework, standardised terminology, common metrics and best practices (Huan, Sheoran and Wang

2004). With regard to the construction industry, Nai-Hsin et al. (2010) used SCOR and simulation techniques to evaluate supply chain performance in a bridge construction project, Pan et al. (2011) study supply and demand behaviour through SCOR using a bridge superstructure construction process as a case study, Thunberg and Persson (2014) used SCOR to measure a construction projects logistics performance, and Wibowo and Sholeh (2015) used SCOR to measure performance in a construction project. The Balanced Scorecard prescribes four perspectives of organisational improvement (financial perspective, customer perspective, internal business perspective, innovation and learning perspective). The Balanced Scorecard has been widely accepted by practitioners and academics in many fields, including supply chain management. Abu-suleiman et al. (2004) identified two basic weaknesses of the tool: first, it describes a one way, top down, approach to performance improvement, and second, it provides a conceptual framework only. This framework has been used in the literature in order to improve performance of construction supply chains. The tool has been used in the construction industry. For example, Halman and Voordijk (2012) used the Balanced Scorecard to measure performance management in house building. Finally, in some cases, for example in the work of Abu-suleiman et al. (2004), both SCOR and Balanced Scorecard have been merged to produce a new tool that is aligned with strategy, is process focused, and integrates fact-based feedback with human judgment in the metrics definition phase. In any case, in order to implement a tool such as the aforementioned, the organisations have to map their processes and identify their level of maturity. The concept of process maturity proposes that a process has a lifecycle that is assessed by the extent to which the process is explicitly defined, managed, measured and controlled (Lockamy and McCormack 2004). Trkman et al. (2010) identified that a low level of process maturity still allows organisations to obtain the benefits of business analytics, although impact of business analytics at lower levels of maturity is much weaker. Supply chain process maturity importantly influences the business processes of an organisation and, consequently, its performance (Oliveira, McCormack and Trkman 2012). The construction process maturity related literature is dominated by the SPICE framework (Hutchinson and Finnemore 1999, Finnemore and Sarshar 2002, Sarshar et al. 2000, Amaratunga et al. 2003, Coletta 2011). It is a five level framework built on the Software Capability Maturity Model (CMM) (Paulk et al. 1993), and provides an assessment tool for the maturity of construction processes. According to Coletta (2011), processes have to be at least at the third level of the model in order for critical functions such as decision analysis, risk management and integrated project management to be executed efficiently. The SPICE framework is a versatile tool. Except from analysing process maturity it can be used as a team building tool throughout a construction project that can help identify potential risk areas in an existing project team and be used as an assessment tool during team formation and selection leading to more predictable and reliable project outcomes (Hutchinson and Finnemore 1999). Finally, Vaidyanathan and Howell (2007) propose a four level maturity model for evaluating construction supply chain processes.

4.6.2. Key performance indicator development process model

The interviews conducted showed that only large contractors have applied some level of process management through the adoption of ISO standards and they measure process performance through the KPIs provided by these standards. This means that there is a need for a process management framework that can be adopted by any construction company. The model described in this section is comprised of two processes (**Figure 58**). The processes are support process according to the categorisation provided by Porter (1985).

They do not need to be executed sequentially, but sequential or parallel execution can provide better results. The first process is “Process maturity assessment”. The underlying premise of process maturity modelling is that the quality of a product is directly related to the quality of the process used to develop that product (Paulk et al. 1993). Hutchinson and Finnemore (1999) found increasing evidence from other sectors that continuous process improvement is based on many small, evolutionary steps, rather than revolutionary measures. Willis and Rankin (2012) refer to this evolutionary path as the process maturity framework and they agree with the general consensus that it consists of various stages of progression, which when adhered to, increase the effectiveness of a process in achieving its objectives. The second process is “Develop KPI framework”. It is important that the previous process is executed prior to this one at least one time before the model is adopted. As Oliveira et al. (2012) argue, the effect of business analytics on performance depends on the supply chain process maturity of the organisation. The KPI framework should have a holistic system perspective beyond the organisational boundaries (Chan and Qi 2003). Cai et al. (2009) propose that a performance management system should include many management processes such as identifying measures, defining targets, planning, communication, monitoring, reporting and feedback. Li et al. (2006) support that higher levels of supply chain management practice, such as a higher level and quality of information sharing, can lead to an enhanced competitive advantage and improved performance. Measurements guide the contractors in process improvement and therefore improve overall construction project performance (Thunberg and Persson 2014). Improved project performance can lead to more successful projects, as success in projects is usually referenced to and measured by the degree of conformance to a predetermined standard of performance (Parfitt and Sanvido 1993). It must be noted that there is no ‘single truth’ on how these processes must be executed, a comment that was provided in the specialised interview. This means that the processes described in this model are open to high levels of adjustments based on each practitioner’s experience. Yet, as interviews with specialists in the construction showed that there is a lack of such practices, their presentation is of great importance.

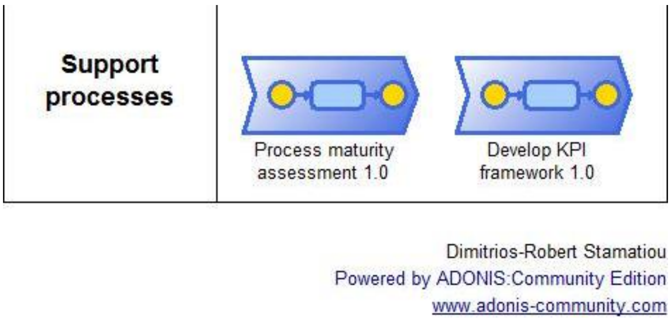

Figure 58: KPI development functions

4.6.2.1. Process maturity assessment

Process maturity assessment is an internal company process. It may be imposed by a client contract clause or by intra-organisational strategy. Before describing the “Process maturity assessment” process, the process maturity levels are briefly described. Paulk et al. (1993) defined maturity levels as follows:

“A maturity level is a well-defined evolutionary plateau toward achieving a mature process. Each maturity level provides a layer in the foundation for continuous process improvement. Each level comprises a set of process goals that, when satisfied, stabilise an important

component in the process. Achieving each level of the maturity framework establishes a different component in the process, resulting in an increase in the process capability of the organisation."

According to Oliveira et al. (2012) and the SCPM3 framework they developed, the five levels of supply chain process maturity are as follows:

- Level 1 – Foundation: Characterised by building a basic structure, aiming to create a foundation for the processes to avoid ad hoc procedures and to stabilise and document processes.
- Level 2 – Structure: Processes start to be structured, with clearly defined characteristics such as beginning, end, inputs, outputs, and structure, in order to be further integrated.
- Level 3 – Vision: Key processes of distribution, planning of the supply chain network, demand planning, procurement and operations have formal process owners.
- Level 4 – Integration: Companies seek to build a collaborative environment with their supply chain business partners.
- Level 5 – Dynamics: Characterised by the strategic integration of the supply chain, when processes support collaborative practices between partners and enable the supply chain to be responsive to market changes.

More specific to the construction industry, the SPICE maturity model (Sarshar et al. 2000) has the following five classifications for process maturity:

- Level 1 – Initial: Project visibility and predictability are poor.
- Level 2 – Repeatable: There is a degree of project predictability.
- Level 3 – Defined: Management and engineering activities are documented, standardised and integrated into the organisation.
- Level 4 – Managed: Organisations have the capability to set quality goals for the product, the process, and the supply chain relationships.
- Level 5 – Optimising: The entire supply chain is focused on continuous process improvement.

The following process (**Figure 61**) described is intended for use in the context of construction supply chain management but, it can be used in order to determine any organisational process maturity level. It is based on the work presented by Chan and Qi (2003). The first sub-process, 'Identify and link all inter- and intra-organisation processes', is critical in order to start understanding where the organisations processes stand and how operations are executed. It is the task of process discovery, defined as "*the act of gathering information about an existing process and organizing it in terms of an as-is process model*" by Dumas et al. (2013). According to Dumas et al. (2013), this sub-process is comprised of the following four tasks (**Figure 59**): 'Define the setting' that relates to assembling a team in a company that will perform process discovery, 'Gather information' that relates to building an understanding of the processes, 'Conduct the modelling task' that deals with organising the creation of the process models, and 'Assure process model quality' that aims to guarantee that the resulting process models meet different quality criteria.

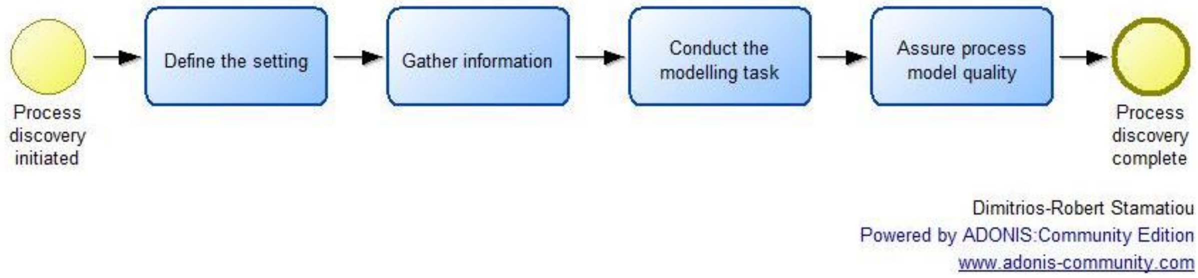

Figure 59: Identify and link all inter- and intra-organisation processes

This will allow the organisation to 'Determine level of process maturity'. Any of the process maturity assessment frameworks mentioned previously can provide support for this task. The next task is to 'Define and confine core processes'. It is important to determine core processes first because, heading straight on to defining all process at one go may prove to be a difficult task since the majority of construction companies are small and medium enterprises (SMEs) and often do not have a clear boundary between business functional units (Cheng, Law, Bjornsson, Jones and R. D. Sriram 2010). Next, the organisation must 'Derive missions, responsibilities, and functions of core processes' in order to identify value adding and non-value adding activities (Chan and Qi 2003). This will allow for the introduction of informed measures in the performance measurement process. Additionally, this task supports decisions related to how to structure the supply chain management activities in order to enable the study of the importance of each area at different maturity levels (Oliveira, McCormack and Trkman 2012). The specialised interview identified that the 'Define goal of modelling' task is very important since it provides the guidelines and expectations for the maturity assessment. Next, 'Decompose and identify the sub-processes' is the next sub-process in the process. Sub-processes include more detailed workflows of certain tasks and provide valuable information for business analytics undertakings. As seen in **Figure 60**, the sub-process is comprised of the following five tasks described by Dumas et al. (2013): 'Identify the process boundaries', 'Identify activities and events', 'Identify resources and their handovers', 'Identify the control flow', and 'Identify additional elements'.

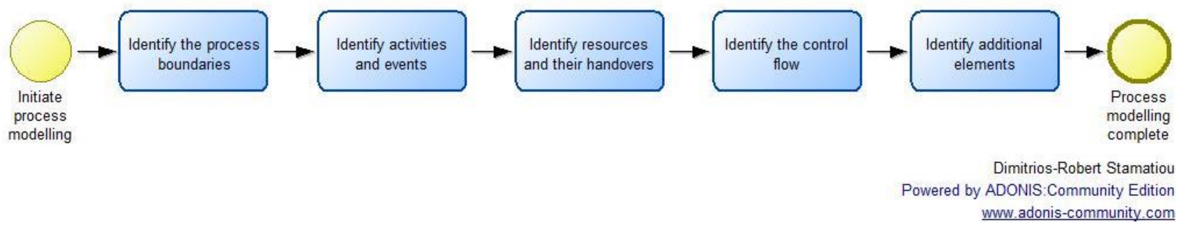

Figure 60: Decompose and identify the sub-processes

Again, the organisation should 'Derive responsibilities and functions of sub-processes'. In the case of sub-processes, this task will provide highly detailed reports of communication, responsibilities and operational directions (Chan and Qi 2003). To support this task, Roy et al. (2005) propose the use of process sheets, which are dynamic documents for communication between technical staff in the head-office, regional staff with knowledge of local customs, and production personnel on site. Process sheets produced in this task provide valuable input to the 'Decompose and identify elementary activities of sub-processes' task. This task allows even further filtering of non-value adding activities and provides a basis for business process redesign projects. These projects can improve business processes, increase the business process orientation and improve efficiency/business performance (Trkman et al. 2010). Next, in order to move processes at a higher maturity level, the organisation must 'Link goals to each hierarchy from process to elementary activity'. This implies that common goals are set for the entire system of processes (Chan and Qi 2003). The quality of the processes identified up to this point is very important. Vanderfeesten et al. (2007) identified the following quality metrics for business processes: coupling, cohesion, complexity, modularity, and size. It is important to evaluate discovered processes against these metrics if there is any gain to be made through this process. Finally, the organisation has to 'Ensure structured change management'. This includes communication, training, and demonstrated commitment by business leaders (Jenkins, Ibarra and Roussel 2001) to all the targets and systems that have been put in place.

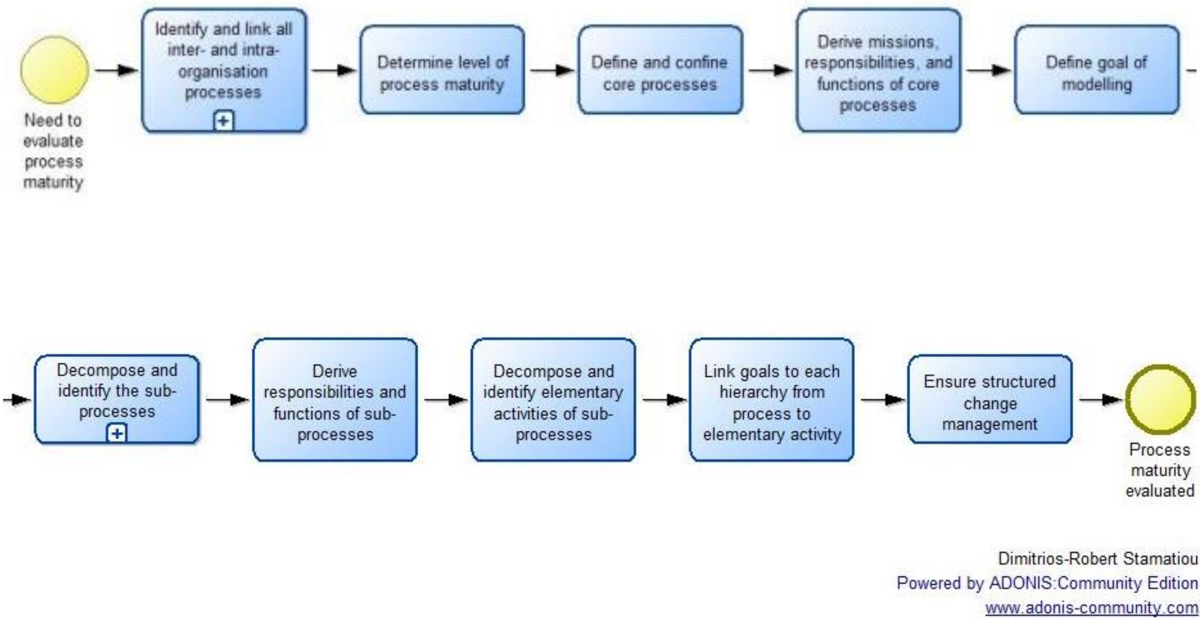

Figure 61: Process maturity assessment process

4.6.2.2. Develop Key Performance Indicator framework model

Each performance indicator can be measured, either quantitatively or qualitatively. Halman and Voordijk (2012) use both financial and nonfinancial measures of supply chain performance in their supply chain performance framework for house-building firms. To set a KPI (Key Performance Indicator) framework a complex process has to be followed (**Figure 65**). First, the contractor has to 'Determine project needs'. The objectives of cost, time, quality, productivity, and efficiency in construction projects vary from project to project (Thiengburanathum and Diekmann 2002). Not all projects need to be measured with the same KPI system. Next, the contractor has to "Select appropriate measuring mechanisms". This sub-process was underlined as extremely important in the interview with the business process management consultant. It contains three tasks (**Figure 62**), as presented by Jenkins et al. (2001). The first task is to 'Define mechanisms and processes for tracking progress'. Next, the task 'Define mechanisms and processes for managing performance' is executed. Both aforementioned tasks include "*identifying data sources, defining detailed* *calculations, and agreeing on what makes sense to track automatically rather than manually*" (Jenkins, Ibarra and Roussel 2001). The last task in this sub-process, 'Define common performance measurements within the organisation and between suppliers/customers' includes common data definitions, calendars, and decision-making rules mainly, but not only, between key supply chain actors. Which business processes to support with business analytics has to be established and how added value is to be achieved must be identified (Laursen & Thorlund 2010, as seen in Oliveira et al. 2012).

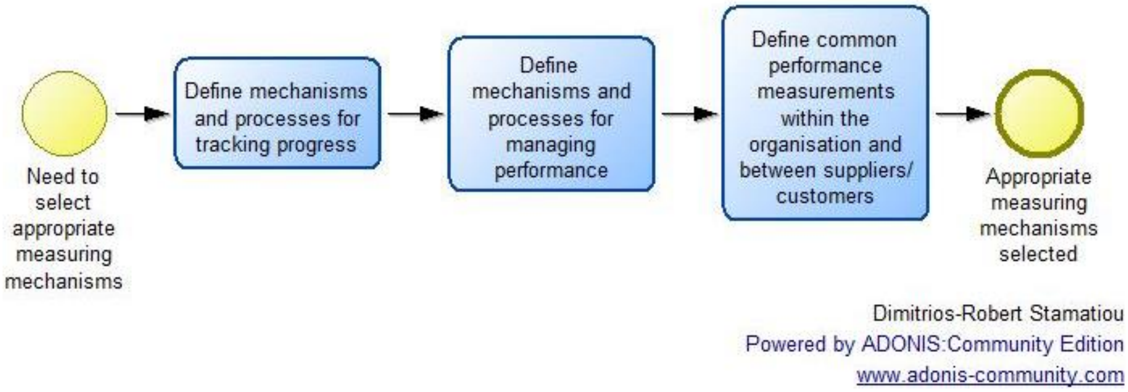

Figure 62: Select appropriate measuring mechanisms

The sub-process is followed by the 'Determine measurement method and intervals' task that was identified through the specialised interview. Selecting the correct method and time intervals for measurement will greatly increase the efficiency of the measurement process. The next task in the main process is to 'Define supply chain decision-making processes and workflows'. This task aims at highlighting decisions that are important for the supply chains of each and every project. Despite the uniqueness of each project, many decisions and the processes that lead to them are similar in more than one project, thus it is good practice to document them thoroughly for future reference. Following this task, the 'Define data requirements' sub-process (**Figure 63**) is next. This sub-process contains four tasks. These tasks, following the sequence described by Jenkins et al. (2001), are: 'Identify and provide access to data requirements', 'Examine available performance management software market', 'Define software solution requirements' and 'Select software solution'. Because of the massive amount of data produced in modern organisations, it is important to follow this sub-process in order to select the appropriate data management methods and tools. Each organisation has differing data management needs and capabilities and there are plenty of software solutions in the market to cover these requirements.

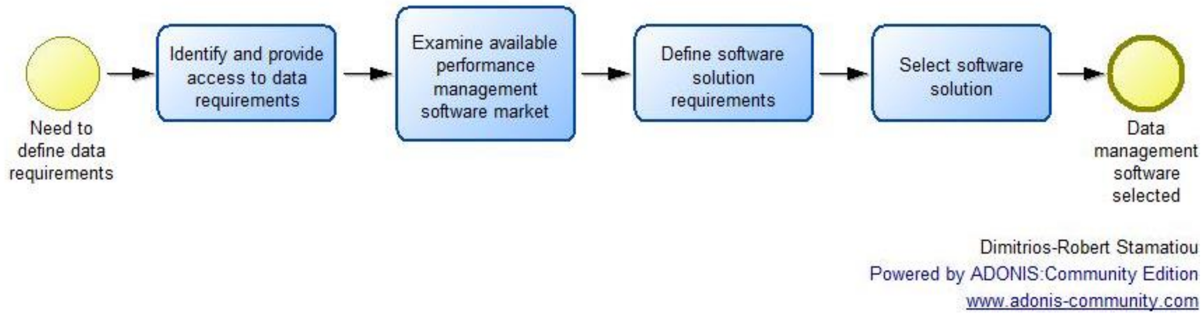

Figure 63: Define data requirements

Back to the main process, the next task that follows is of critical importance as mentioned in the specialised interview. The contractor must 'Develop guidelines for service level agreement commitments'. Service level agreements are official commitments between service providers and clients to certain targets for the level of the offered service (Kearney and Torelli 2011). Then, the contractor must 'Define performance indicators for all functions'. Zeng and Shu (2010) stress out that the selection of performance indicators should achieve balance in many aspects, so as to construct a sound performance evaluation system. They go on to support that "*A good performance indicator system includes not only reflect the short-term and long-term goals, internal and external level indicators, also includes leading indicators and lagging indicators, quantitative indicators and qualitative indicators of the balance between.*" There is ample evidence in the literature that shows that the combination of Balanced Scorecard and SCOR can provide useful categorisation and targeting of metrics (Abu-suleiman, Boardman and Priest 2004, Piotrowicz and Cuthbertson 2015). The specialised interview pointed out that in case there is no available material, the APQC-PCF framework (American Productivity and Quality Center 2017) can provide a very good starting point. This task may, in many cases, have input from suppliers and clients or output to these parties. This input/output will be in the form of contract imposed KPIs by any party, usually regarding financial measures. Thunberg and Persson (2014) encourage contractors to assess supplier performance and vice versa in order for systematic supplier mistakes to be detected and allow the two sides to remedy the problems. Customer-based measures are important, but they must be translated into measures of what the company must do internally to meet its customers' expectations (Kaplan and Norton 1992). Most indicators will be related to productivity on the worksite, but Sacks et al. (2017) highlight that with the exception of the most repetitive of construction projects, optimal production flow is highly unlikely to coincide with achieving optimal productivity. Since sustainability is a hot topic in most industries, the contractor has to take into consideration that the client or regulations might be imposing sustainability metrics to the supply chain (Ravetz 2008). 'Relate performance indicators to targets' is an important task where the indicators are set to measure critical parameters of the project according to the contract performance requirements or against the strategically selected internal areas of improvement. Moving forward in the process, the 'Relate performance indicators to supplier and customer profitability' sub-process involves six tasks, as described by Enz and Lambert (2012). How supply chain collaboration in different projects influences the performance outcomes of these projects, and thus gives evidence of the appropriateness and effectiveness of supply chain collaboration has to be identified (Vrijhoef et al. 2014). As seen in **Figure 64**, these tasks are as follows. First, the contractor has to 'Identify joint initiatives'. Next, depending on the availability or not of profitability/total cost reports, different tasks are executed. In the first case, that of availability of reports, the ‘Quantify revenues and costs associated with joint initiatives’ task is executed. This task aims to collect financial information in order to quantify the outcomes from the joint initiatives identified (Enz and Lambert 2012). In the second case, that of unavailability of reports, two tasks are executed sequentially. First, the contractor has to ‘Determine cost and revenue data to be obtained’. This task involves identifying sources of data and methods of analysing the sourced data. The ‘Calculate value co-creation for each actor’ task uses the data and methods selected in the previous task to determine how each actor contributes to value creation. Both process streams merge at the ‘Analyse financial data, track performance and make decisions’ task. During this task the contractor communicates with other key supply chain actors about the value co-creation and the targets set. Finally, the task ‘Set goals for value co-creation’, that determines new goals for future value co-creation, concludes the sub-process. This whole sub-process encourages the view of a project as a value co-creation process and collaboration opportunity.

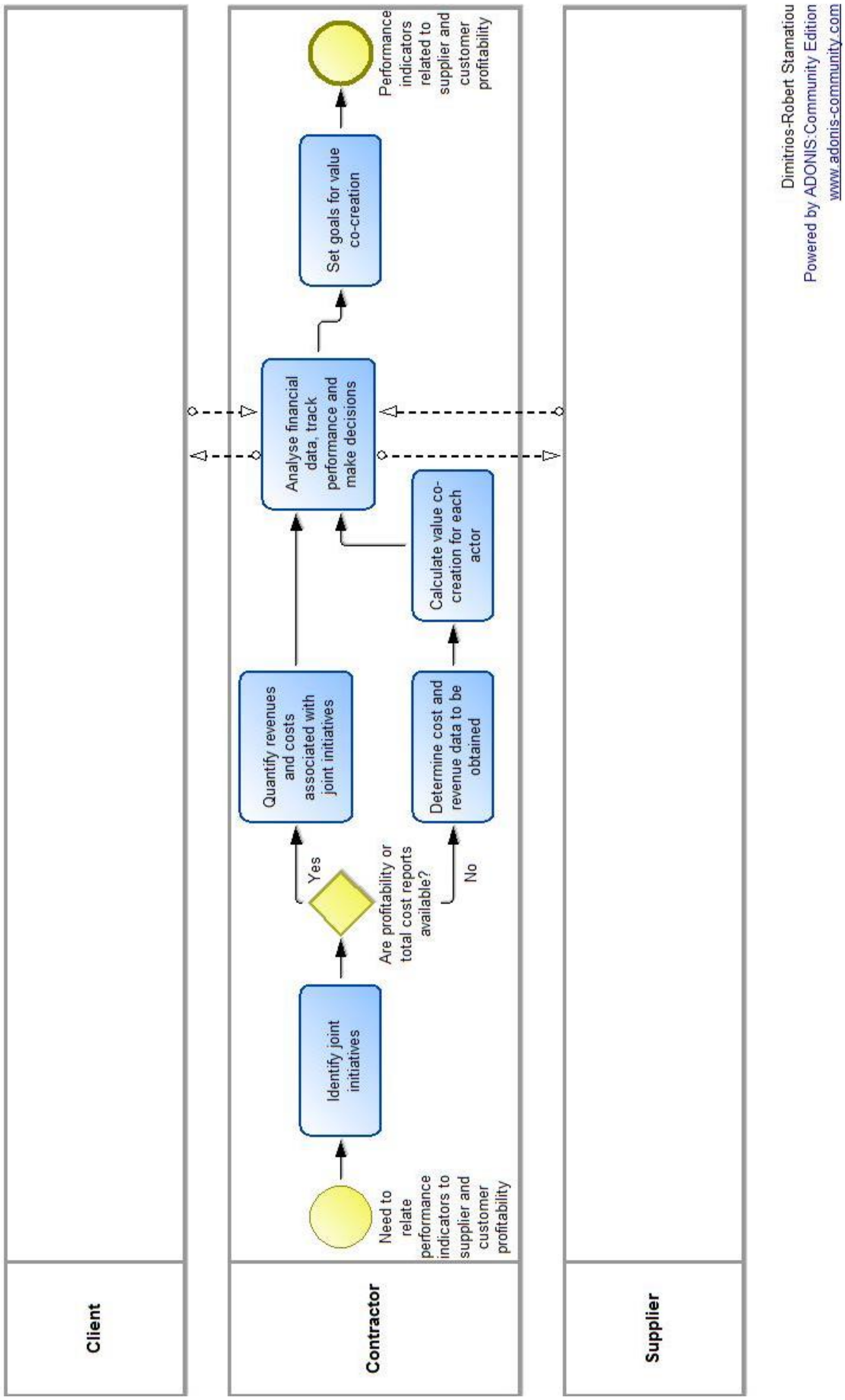

Figure 64: Relate performance indicators to supplier and customer profitability (adapted from Enz & Lambert 2012, pg. 500)

It is imperative to ‘Develop framework to compare performance indicators with those of competitors’ in order to obtain a measure of comparison of the organisation’s performance and to identify strengths, weaknesses, opportunities and threats. It is advisable, even for existing KPI frameworks, but especially for newly developed frameworks to ‘Establish communication and feedback loops’. This task, in particular, allows for continuous monitoring of the KPI framework, and, in the case of KPIs that have been imposed by other actors or upon other actors, it allows communication about the applicability and effectiveness of these indicators. The task ‘Locate erroneous performance indicators’ is the next step in the process. It involves identifying, resolving and enhancing performance indicators that the feedback or their use proves that they do not function as designed/intended. It provides means to compare the performance according to multiple criteria. It should also allow for normalising different scores and identify measure conflicts. This could be done using strategy maps that help identify any missing links between metrics and strategy (Abu-suleiman, Boardman and Priest 2004). The final task, ‘Determine performance indicator re-examination period’ refers to the selection of a timeline for examining the applicability, usage and other parameters of the selected KPIs.

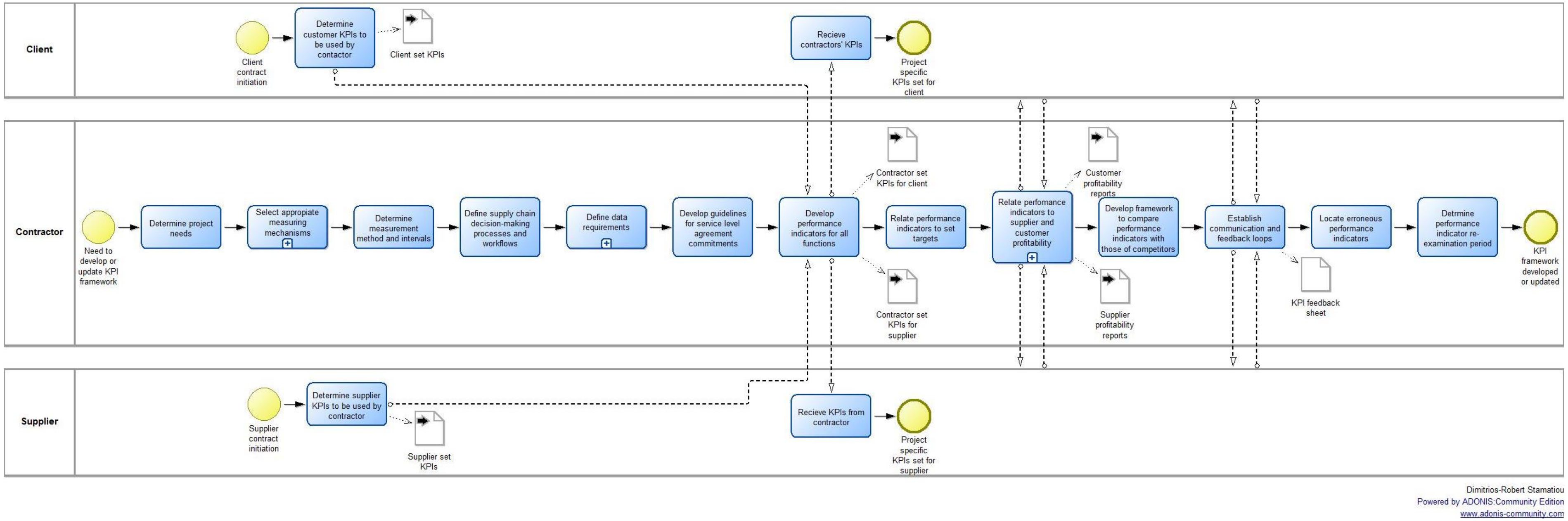

Figure 65: Develop KPI framework

4.7. Demand management

4.7.1. Analysis of demand management

Demand in construction cannot be satisfied the moment it is created. Construction is a typical engineer-to-order supply chain (Mello, Strandhagen and Alfnes 2015), with every project creating a new product or prototype. Engineer-to-order supply chains are characterised by long lag times (Grenadier 1995). Reduction of lead times and improvement of estimate reliability are key to improving delivery of engineer-to-order supply chains (Mello, Strandhagen and Alfnes 2015). Demand levels are hard to forecast and construction markets are affected by many parameters. Guffond and Leconte (2000) underline that "*the European construction industry is still bound by constraints of variability*". But a similar situation can be noted in every country or continent due to the general economic conditions that greatly affect construction and make demand in the sector very volatile with dramatic fluctuations (Fan, Thomas Ng and Wong 2007). Unforeseen regional or global economic events also affect the volume of demand for construction at a fundamental level (Fan, Ng and Wong 2010). In addition, public sector procurement practices and policies affect the market environment and create big fluctuations in demand (Caerteling, Halman and Dorée 2008). Misapprehensions concerning future economic conditions are the reason projects get postponed or abandoned before the tendering stage (Akintoye and Skitmore 1994) and lack of growth in construction is tangled in a vicious circle with austere financial periods (Forbes et al. 2012). Demand uncertainty greatly impacts supply chain operations (Vidalakis, Tookey and Sommerville 2013, Fildes and Kingsman 2011). Soo and Lan Oo (2014) found that the industry defines construction demand as: the number of/the number requirement of buildings to be constructed, which means there is an analogy between rises in demand and the amount of projects available to bid for. It is important for construction contractors to understand future demand variations in order to select appropriate pricing strategies that will allow survival in a highly competitive market (Jiang and Liu 2014). Knowledge of future demand is important at many levels (GOH 1998): the enterprise level, the activities level and the project level.

Rosen (1984) proposed that demand for office space can be forecasted using tools that manufacturers use to forecast demand for their goods. Demand forecasts for contractors relate to new projects; awarded contracts consist work in progress and send demand signals upstream the supply chain. With this in mind, the demand management process that follows is the contractors' link with customers, supply chain partners and suppliers (Benton 2013) and has a significant impact on the profitability of both the contractor and the entire supply chain (Croxton et al. 2002). It is not enough though just to manage demand, it must be managed effectively in order to take full advantage of available company resources. Demand management is tightly connected to vision and strategy definition, on-going projects, project assessment, budgeting, prioritisation and selection, portfolio governance and communication, portfolio implementation, portfolio reporting, strategy and portfolio review, and benefits realisation (Romano, Grimaldi and Colasuonno 2016).

Demand changes in volume and market structure impact the level of activity and type of work available to the construction contractors. As Croxton et al. (2002) describe, "*the goal of demand management is to meet customer demand in the most effective and efficient way*". Runeson and Skitmore (1999) suggest that demand is one of the most impactful factors of construction tendering prices. Demand for construction services affects contractor workloads and ultimately their decisions on the tender prices they will submit. Knowledge of changes in demand is a parameter that heavily affects a contractor's strategic actions (Akintoye and Skitmore 1994). Demand in construction can be divided in to final product demand and demand in service by final product (Alasad, Motawa and Ogunlana 2012). Uncertainty of demand is a key characteristic of the construction industry (Naim and Barlow 2003, Ala-Risku and Kärkkäinen 2006) that can be attributed to the unique nature of each project, the range of materials required, construction site location uncertainty and seasonality in workloads (Vidalakis, Tookey and Sommerville 2013). In their other work, Vidalakis et al. (2011) listed the following additional factors affecting demand uncertainty in construction: highly fluctuating levels of demand with peaks in correspondence with demand for construction projects, demand levels for particular products and materials follow specific project requirements, demand for made-to-order products, demand levels cannot be communicated upstream the supply chain prior to contract nomination, unforeseen demand cannot be satisfied due to contractors' limited ability to maintain buffer inventories, and high levels of demand increase demand for transportation capacity which is not always followed by proportional income increase, due to the high volume and low value of construction components and raw materials. This uncertainty is spread upstream of the supply chain affecting manufacturers of construction components. These manufacturers face two types of demand according to van Donselaar et al. (2001): "*regular demand from many small orders and very irregular, lumpy demand from infrequent, large orders*". It is difficult to forecast demand before contracts are nominated because bidding teams cannot provide exact information to determine the levels of demand for their suppliers (Arbulu, Ballard and Harper 2003). It is common for suppliers to complain about the bad quality of and unreliability of the forecasts they are handed (Carlsson 2008).

Bon (1992) described the influence of economic growth on the role of the construction sector. In his work he describes the relationship of construction monetary output and volume to GNP growth as an inverted U where the turning points coincide with the transformation of a country into a newly industrialised country and then to an advanced industrial country. Furthermore, Bon added that the type of demand would also transform from new construction work to repair and maintenance. Gruneberg (2010) tested Bon's theory and concluded that the level of infrastructure demand may decline or may reach a level of stability (after the first turning point) following the initial burst of activity that establishes most of the infrastructure. Jiang and Liu (2014) characterise reliable forecasts of aggregate demand for construction as of vital importance to developers, builders and policymakers and propose the use of forecasts at a regional construction market level. As a fact, despite the obvious benefits resulting from demand forecasting, it has attracted limited attention in research and practical arenas (Fan, Ng and Wong 2010).

Fluctuating market demand means that construction-related organisations work with competitive tendering and small profit margins in order to survive (Soetanto et al. 2006). Fluctuations in demand don't just affect the contractors. As is the case in other industries, fluctuations of demand at the clients' level have a ripple effect upstream of the supply chain and result in huge variability for suppliers; this is the bullwhip effect. Orders placed by upstream nodes demonstrate higher variability compared to orders placed by their downstream partners (Chatfield et al. 2004). The bullwhip effect affects both individual companies and their supply chain (Zotteri 2013). A coordinated effort to monitor changes in existing construction markets and to predict future demand is absent in the industry which leads to an imbalanced and distorted production capacity (Fan, Thomas Ng and Wong 2007). This lack of coordination between supply chain partners is the root cause of all the problems created at a behavioural and operational level by the bullwhip effect (Bhattacharya and Bandyopadhyay 2010). One has to keep in mind though, that unlike seasonal or cyclical demand changes in manufacturing, construction demand swings are attributed to activity planning and execution (Hamzeh et al. 2007).

Construction companies lack vision regarding their demand management strategies. Construction companies restrict their supply strategies to project delivery and only few advanced supply strategies include facility management, maintenance and refurbishment (Ridder and Vrijhoef 2008). Jiang and Liu (2014) underline that governments play a pivotal role in ensuring sustainability and healthy development in the construction industry. Current construction strategies handle changes in demand through changes in product prices and the industry adapts by changing its capacity (Ngai et al. 2002). But this is problematic when considering public clients. Public clients tend to work with fixed and restrictive budgets, while public projects are scrutinised by government agencies to ensure value for money, control over public funds and that public interest is met (Ridder and Vrijhoef 2008). In case of economic hardships though, governments may be the main contributors to construction demand by facilitating supplies, raising demand for construction work, building up a strategic alliance with the industry or keeping a stable work load (Chiang, Tang and Leung 2001). In order to assist policy makers to make the correct decisions to support local construction against business cycle- related fluctuations, a reliable set of demand forecasts is required (Wong, Chan and Chiang 2007).

Demand in service by final product relates to the demand for the service of a specific project such as a toll-road. This kind of demand can affect the decision of contractors to form concessions and bid for a specific project. As Alasad et al. (2012) posit, demand risk appears at the operation volume and the relative revenue, thus forecasts of the service demand have to be well informed when deciding, planning and operating these kinds of projects. Bain (2009) identified huge discrepancies between the forecasted and actual demand for service ranging from 86% below to 51% above the forecast. Flyvbjerg and Holm (2005) came to similar conclusions after examining over two-hundred projects at an international level. Alasad et al. (2012) identified the following sources of demand inaccuracy in service forecasting in the literature: inadequacy of the model structure, inaccuracy of the current data, uncertainty in prediction of the future value of exogenous variables, technical mistakes in the methodology, strategic behaviour of the bidders (optimism and bias) and uncertainty in model design and structure.

Bid decisions are tightly related to both types of demand for construction projects. van Donselaar et al. (2001) highlight the fact that "*projects vary in terms of the quality and timing of advanced demand information and the probability of winning a bid*". Soo and Lan Oo (2014) identified the following factors affecting the decision to bid in the literature: need for work, number of competitors tendering, experience in such projects, current workload, client identity, type of job, historic profit, and degree of hazard. Soo and Lan Oo (2014) also identified the following factors affecting the pricing of their service in literature: degree of difficulty, risk, current workload, type of job, need for work, uncertainty of estimates, historic profit, and contract conditions. Akintoye and Skitmore (1994) propose the inclusion of both the client ability and willingness to pay when modelling demand for capital investment.

There are many tools available in the literature related to demand forecasts, both quantitative and qualitative. Statistical methods were proposed by Rosen back in 1984 as a tool for forecasting supply and demand of office space. Quantitative methods provide more objectivity (Jiang and Liu 2014), but factors from both categories play an almost equivalent role in shaping demand (Alasad, Motawa and Ogunlana 2012). Pindyck and Rubinfeld (1976) (as seen in Akintoye and Skitmore (1994)) classify economic forecasts into three categories: ex post simulation or 'historical' simulation, ex post forecasting and ex ante forecasting. There are two types of forecasting tools: univariate and causal models (Fan, Ng and Wong 2010). Univariate models use past values of time series to predict future values, whereas causal models identify the variables affecting the variable of interest and describe their relationships through statistical models. A list of some of the forecasting methods used in the literature follows:

- Exponential smoothing (Fan, Thomas Ng and Wong 2007)
- Lake of demand (Alasad, Motawa and Ogunlana 2012)
- Artificial Neural Network (Hua 1996)
- Box-Jenkins model (Hua and Pin 2000, Wong, Chan and Chiang 2005, Fan, Ng and Wong 2010)
- Panel ordinary least squares regression model (Hadavandi et al. 2011, Mak, Choy and Ho 2012)
- Panel vector error correction (Jiang and Liu 2014)
- Grey forecasting (Tan et al. 2015)
- Cross-sectional technique (Ofori and Han 2003)
- Simulation (Vidalakis, Tookey and Sommerville 2011)
- Structural and ARIMA models (Fullerton, Laaksonen and West 2001)
- Multiple regression (Akintoye and Skitmore 1994, Tang, Karasudhi and Tachopiyagoon 1990)
- Vector error correction (Fan, Ng and Wong 2011)

There are benefits and shortcomings in the use of each method. For example, the regression model is strong in outlining the contributing factors towards the variable under study, whereas time series models predict future values solely based on historical trends of the variable (Fan, Thomas Ng and Wong 2007). Most statistical methods cannot support, but can work on small amounts of data, whereas artificial intelligence methods can support interrelations between variables but need large amounts of data to do so (Alasad, Motawa and Ogunlana 2012). User judgement is critical in any forecast method selected. Fan et al. (2007) highlight that intuitive judgment involved while selecting parameters for the forecasts may help overcome lack of information but may also contribute to discrepancies in the final results.

There are many factors that can be taken into consideration during the forecasting process. Akintoye and Skitmore (1994) divide these factors into "*general and local factors*" and propose the use of the PESTL (Political, Economic, Social, Technological and Legal/legislative) tool in order to classify general factors under investigation. Hillebrandt (1985, 2000), as seen in Akintoye and Skitmore (1994) and Soo and Lan Oo (2014) respectively, list the following factors affecting demand: population, interest rate, shocks to economy, the demand for goods, surplus manufacturing capacity, the ability to remodel, government policy (monetary, fiscal, e.g. tax policies), expectation of continued increased demand for manufacturing goods, the expectation of increased profits (on the activities of those that demand construction), and new technology. Local factors include: building types, procurement types and geographical location (Skitmore (1987) as seen in Akintoye & Skitmore (1994)). Other divisions of factors affecting demand forecasts found in the literature are based on type of project. Fan et al. (2007) divide construction demand into residential, industrial, commercial, public works and utilities, and repair and maintenance. Factors affecting the forecast of each project type, as described by Fan et al. (2007) can be seen in **Table 17**.

Table 17: Forecasting factors by project type

Residential	Industrial	Commercial	Public works and utilities	Repair and maintenance
Population	National economy indicators	National economy indicator	Government revenue and expenditure	National economy performance
Interest rates	Performance of the manufacturing sector	Employment distribution	Population structure	Household income
Construction approval/ completion/ transaction volume	Performance of the industrial sector	Performance of the industrial sector		Purchasing power
GDP		National savings		New construction completion
Tender price index		Export value		
Unemployment rate		Land price		
		Productivity		
		Sales		

Furthermore, regarding the residential projects Hua (1996) identified the following factors, in contemporary literature, affecting demand forecasts: national income per capita, general demand for construction, size of population, rate of household formation, interest rate, property price, levels of supply of residential property, disposable income, economic growth, level of unemployment/employment, existing housing stock, rate of inflation, construction cost, mortgage credit availability/supply, and household personal savings. GOH (1998) focused on factors influencing residential construction demand and narrowed them down to: building tender price index, bank lending, population, housing stock, national savings, gross fixed capital formation, and unemployment level. Elsewhere in the literature, Grenadier (1995) highlights the impact of real estate cycles on both residential and commercial construction demand and Jiang and Liu (2014) analyse the effect of geographical areas on demand. Most of these factors have been identified in other works to, such as Akintoye and Skitmore (1994), Fan et al. (2010), Soo and Lan Oo (2014), and Jiang and Liu (2014).

Each type of project has clients with different characteristics ranging from civilians to state authorities. Finance is one of the most important factors in all project types. The economic situation is the prime consideration of both large and medium size contractors, as Dulaimi and Shan (2002) found in their study of the market in Singapore. Akintoye and Skitmore (1994) came to the same conclusion through a simulation process that showed that economic shock, interest rate and demand for goods greatly impact construction demand. Additionally, Hutcheson (1994) identified a strong relationship between construction demand for all types of project and GDP. Regarding residential housing, Buyst (1989) identified that private housing investment in Belgium is affected by national income, ratio of price of rent index and index of construction cost, real interest rates on mortgages and the threat of war. Furthermore, factors of local economy in different geographical regions such as construction price, state income, size of population, unemployment rates, local wages, local topography, local regulatory environment and interest rates may differentiate local demand from national demand levels (Gyourko & Saiz 2006; Jiang & Liu 2014). Finally, rapid urbanisation is due to population and GDP increase and leads to increased urban land demand (Huang et al. 2007).

Arbel et al. (2009) identified empirical evidence indicating a positive correlation between prices and the demand in construction products, but Jiang and Liu (2014) who also identified the same association found a negative relationship. Jiang and Liu (2014) also identified state income, population, unemployment rates and interest rates as factors affecting the construction demand and price relationship. The work of Akintoye and Skitmore (1994) proved there is an elastic association between price and housing demand, but that wasn’t the case with commercial and industrial construction, meaning that these two types of projects present different market characteristics. Additionally, geographical differences in prices also affect the level of demand (Jiang and Liu 2014). Akintoye and Skitmore (1994) suggest the tender price index, an indicator of construction cost accepted by clients, as a window to the potential demand for contractors. But prices are also affected by the contractor’s need for work and current workload, since higher workloads signal higher opportunity costs (Flanagan and Norman 1985, Soo and Lan Oo 2014).

4.7.2. Demand management process model

In order for a company to be proactive to anticipated demand and reactive to unanticipated demand, a good demand management process is required (Croxton et al. 2002). Such a process, according to Wong et al. (2007), allows companies to “*profit from advance knowledge and to avoid disasters by virtue of predicting their occurrence*”. The “Demand management” function is comprised of nine processes; four strategic and five operational (**Figure 66**). Strategic processes are usually executed once or twice a year and can be executed in parallel or sequentially. Strategic processes include “Determine demand forecast processes”, “Plan information flows”, “Determine synchronisation processes” and “Develop contingency management processes”. Operational processes are executed as often as needed and follow a sequential mode with the exception of the performance related process that can be also executed in parallel with all other operational processes. Operational processes include “Forecast input data collection”, “Forecasting”, “Synchronise demand forecast with construction, supply, and logistics”, “Demand variability reduction and/or flexibility increase” and “Demand management performance measurement”. The lack of demand management process models in the literature, especially the construction literature, mean that the processes described in this section are heavily influenced by the work of Croxton et al. (2002).

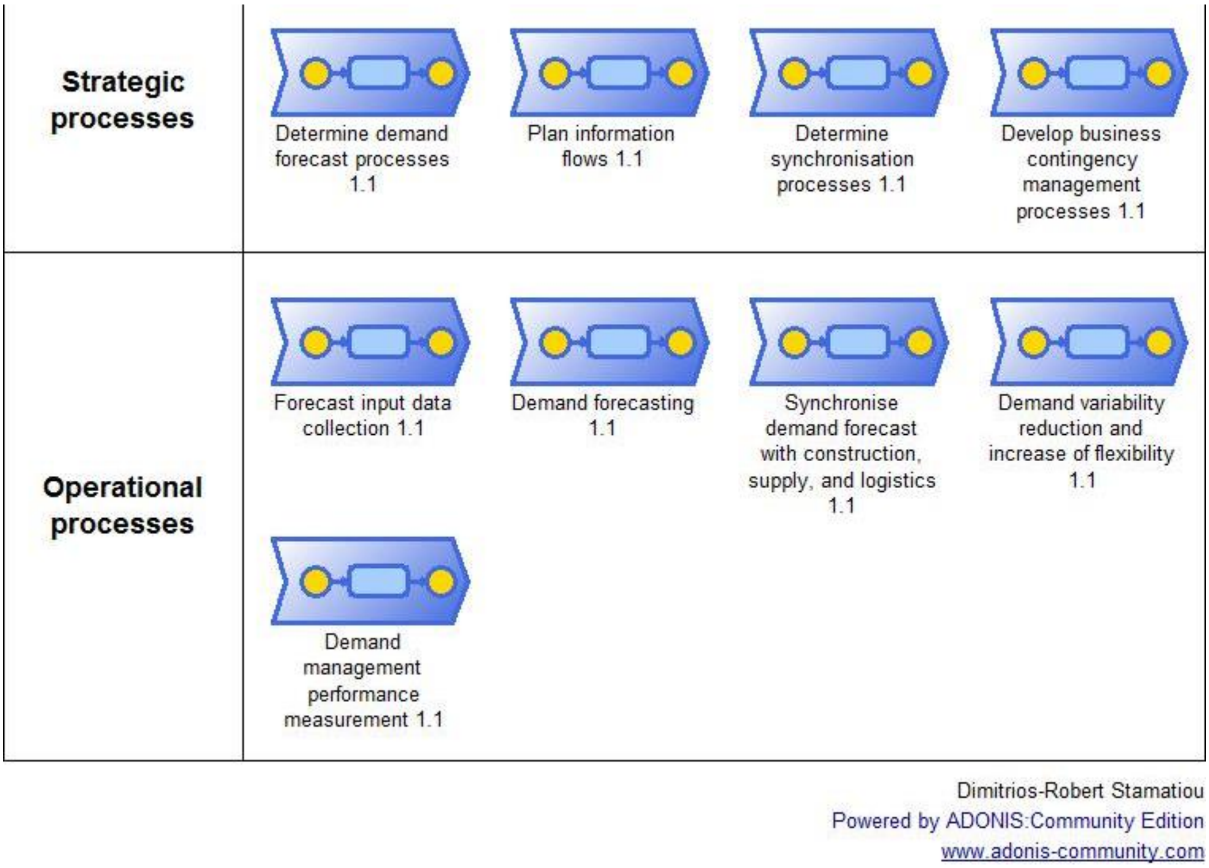

Figure 66: Demand management function tree

4.7.2.1. Strategic processes

The first strategic process is "Determine demand forecast processes" (**Figure 67**) and aims to provide the outline in which the forecasting processes will take place at the operational level. The first task is to 'Determine amount of forecasts and their intervals'. It is common in manufacturing to create a set of demand scenarios from which the company will select the most fitting scenario without being confined by a single point forecast (Christopher and Holweg 2011). These scenarios are updated periodically to ensure that the most recent demand data is taken into consideration. This practice could prove beneficial for construction contractors, especially when doing business in a turbulent market. The division of construction demand into residential/commercial/industrial construction demand, building/civil/repair and maintenance works demand, and public/private sector construction demand allow more accurate and meaningful forecasting models (Bee-Hua 1999). It is imperative to 'Identify data sources for each forecast' in the context of the aforementioned categories. Next, in order to guarantee a certain level of consistency in the forecasts the planning staff must 'Select appropriate forecasting methods'. The most critical factor to the generation of accurate forecasts is the selection of a suitable forecasting technique (Wong, Chan and Chiang 2007). There are many tools available in the literature and each tool may perform better at different project type forecasts, for example Box-Jenkins is proven to work well in residential projects (GOH 1998, Fan, Ng and Wong 2010). It comes without saying that with the vast amount of data that needs to be analysed forecasting cannot be implemented with pen and paper, so it is important to 'Select appropriate forecasting software' to assist the staff performing the process. Finally, the task 'Determine forecast process re-evaluation periods' aims at establishing a periodical evaluation of forecasting processes in order to correct any problems.

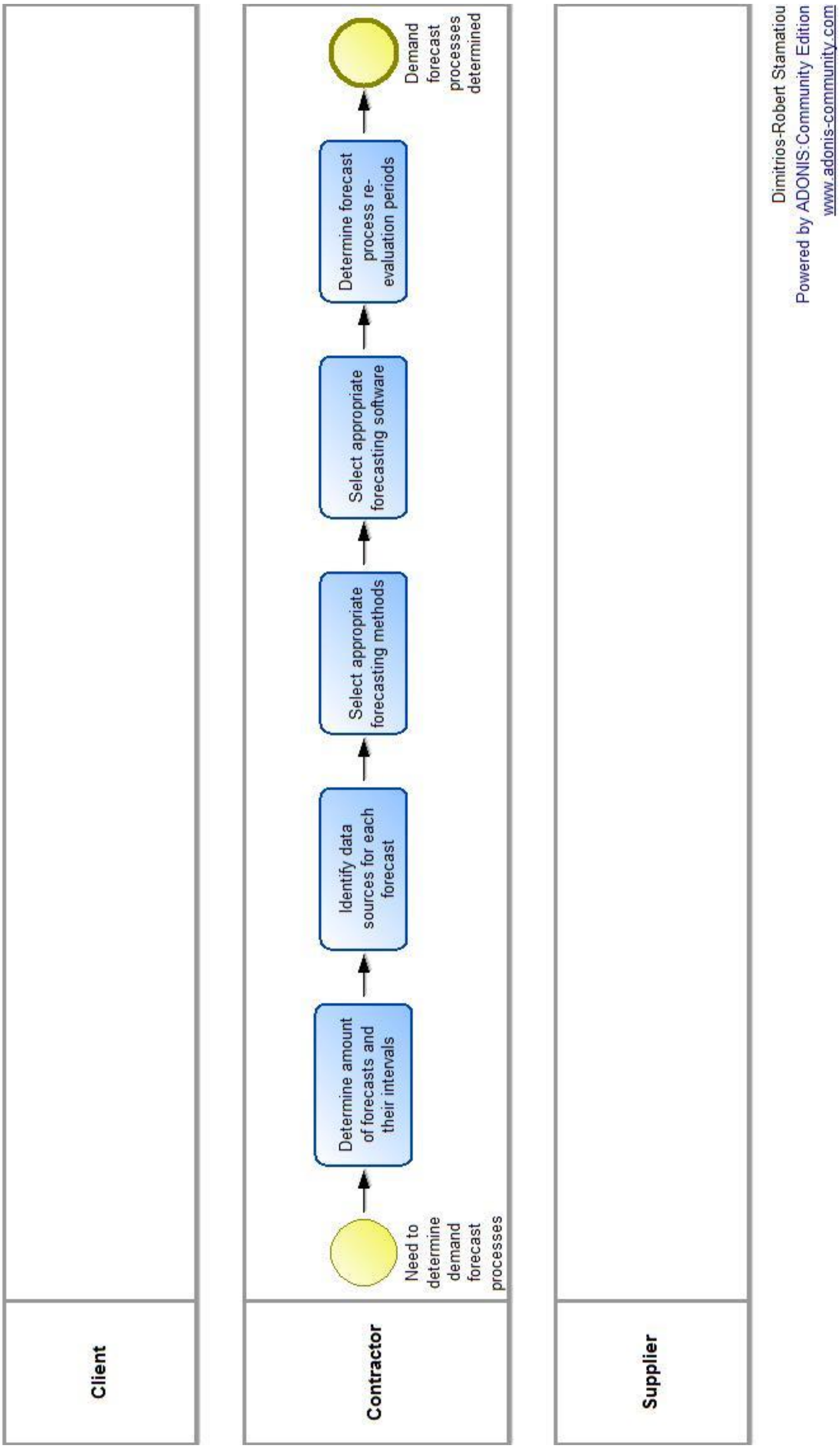

Figure 67: Determine demand forecast processes

The second strategic process is “Plan information flows” (**Figure 68**) and aims at determining the channels of demand forecast related information flow. The first task is to ‘Ascertain data sources to be used’. Data sources and their credibility play the most important role in the accuracy of the forecasts. Such sources may be real estate market performance, local and general government announcements and historical construction demand data. Next, the task ‘Determine data transfer channels’ aims at the predefinition of internal and external (incoming) information flow channels. Regarding outgoing external information flow channels, they should be carefully selected. In an effort to normalise demand patterns upstream of the supply chain, contractors should share advanced demand information with key suppliers (van Donselaar, Rock Kopczak and Wouters 2001) and the purpose of the ‘Determine appropriate systems for forecast data exchange between organisations’ task is to ensure that this sharing is done as efficiently as possible. Next, the contractor must ‘Examine impact of forecast input/output data on business strategy’. This practically means that if demand for new projects is low, maybe a turn to the repair market could be a viable strategic choice. Finally, the task ‘Determine data flow design re-evaluation period’ aims at establishing a periodical evaluation of data and information management processes in order to correct any problems.

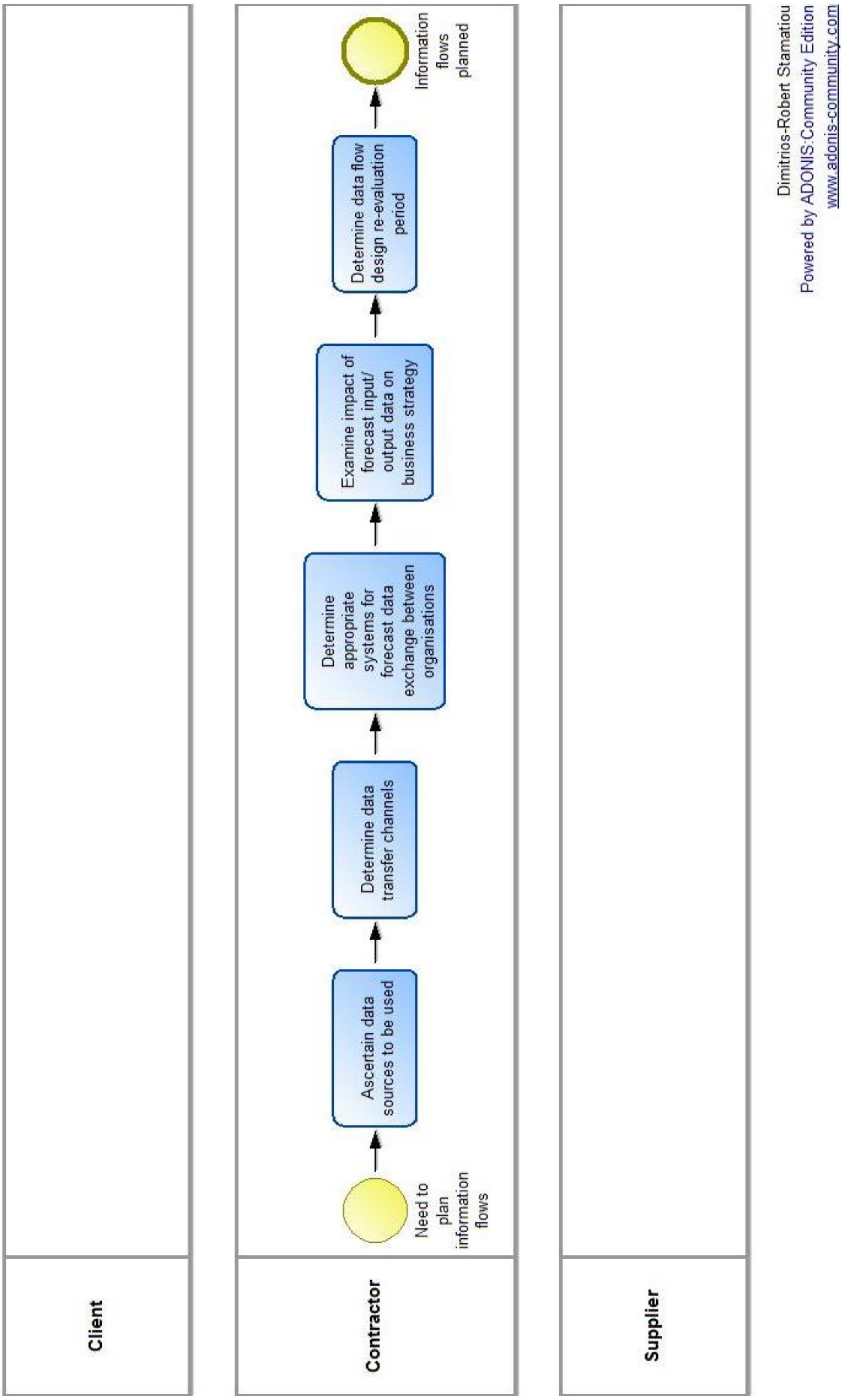

Figure 68: Plan information flows

The third strategic process is “Determine synchronisation processes” (**Figure 69**). Synchronising demand with supply becomes more complex when there is an increased number of actors (Gayialis et al. 2015). The first task is to ‘Examine supply chain capabilities of potential partners’ and identify any bottlenecks in their logistics, supply capabilities or project management skills. Next, the contractor should come up with ways to ‘Balance demand forecast with potential supply chain capabilities’ in order to avoid unpleasant surprises after bidding for projects. It is important to ‘Identify level of flexibility at key supply chain points’ in order to take advantage of the benefits it provides. Finally, the contractor should ‘Negotiate key supplier integration with contractor synchronisation processes’, including software sharing and demand data exchange.

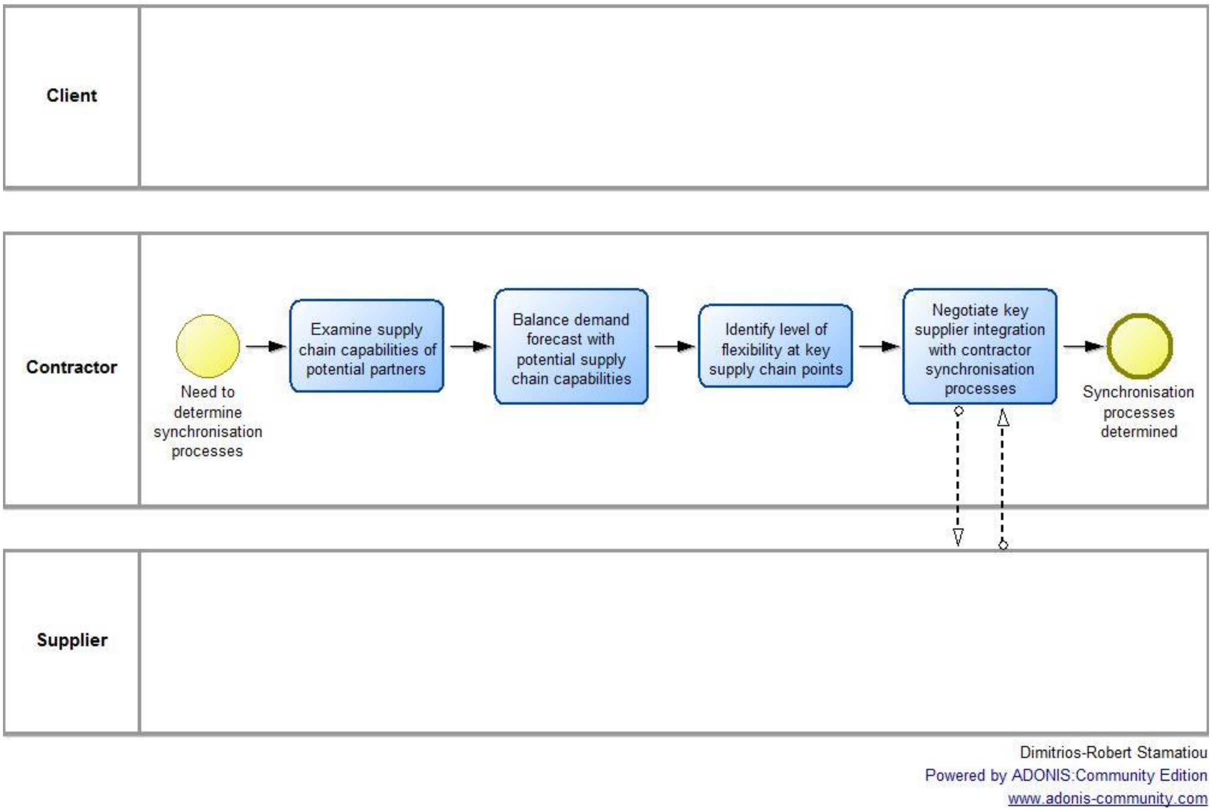

Figure 69: Determine synchronisation processes

The fourth strategic process is “Develop business contingency management system” (**Figure 70**) and relates to the development of a contingency plan in case demand and supply are disrupted at a business level. This involves the identification of risks and opportunities in the market and the selection of countermeasures that will allow the company to continue its business. The first task is to ‘Draw up list of possible external disruptions to supply and demand’. Such disruptions could be related to financial meltdowns, extreme natural phenomena or legislation. The task ‘Determine response processes’ aims at not only coming up with potential responses to such events, but also describing how these responses should be implemented. Next, the contractor must ‘Determine response to data flow interruptions’ and share these response plans with key suppliers in an attempt to recover as fast as possible from such events. Finally, the results of the previous tasks should be organised through the ‘Develop and update business risk catalogue’ task.

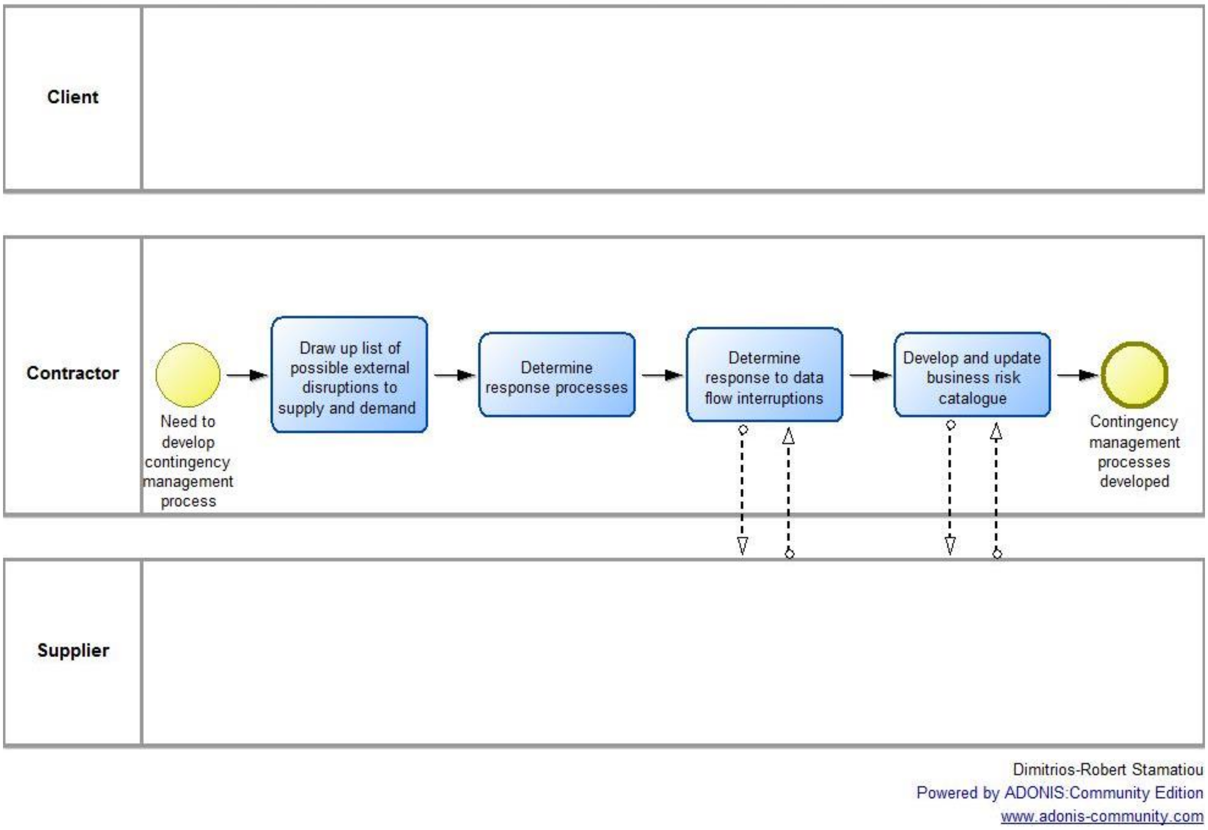

Figure 70: Develop business contingency management processes

4.7.2.2. Operational processes

The first operational process is “Forecast input data collection” (**Figure 71**) and involves all tasks related to sourcing the forecast input data. Interviews revealed that demand data for large contractors originate from invitations to tenders, government institutions, repetitive clients, expansion to niche markets, expansion to new countries, financers, and backlog projection. SME contractors do not trace their demand data to specific sources when considering private clients, but some trends show that mouth-to-mouth, curiosity about ongoing projects, social media, acquaintances, reputation and, rarely, advertising are what bring new clients. Demand sources for public projects include government institutions and calls for tendering in National Strategic Reference Frameworks. The first task is to ‘Examine data from predetermined sources’ including data sources determined at the strategic level, data from clients and data from suppliers. Next, the ‘Collect historical demand data’ task is executed. This task aims at the retrieval of previous demand data, previous demand forecasts and their differences. Construction markets are volatile and the contractor ought to keep a close eye on changing demand patterns. Thus, the task ‘Collect market data’ is executed, where data and reports from statistics authorities or consulting agencies are collected and studied. Next, claims may present a source of demand, especially reworks, so it is important to ‘Collect claims data’ from the client and incorporate it in the demand forecasts. Finally, the ‘Clear all data’ task aims at removing statistical extremities, double entries and other data faults from the data sets that will be used in the forecasting process in order to make the forecast as flawless as possible.

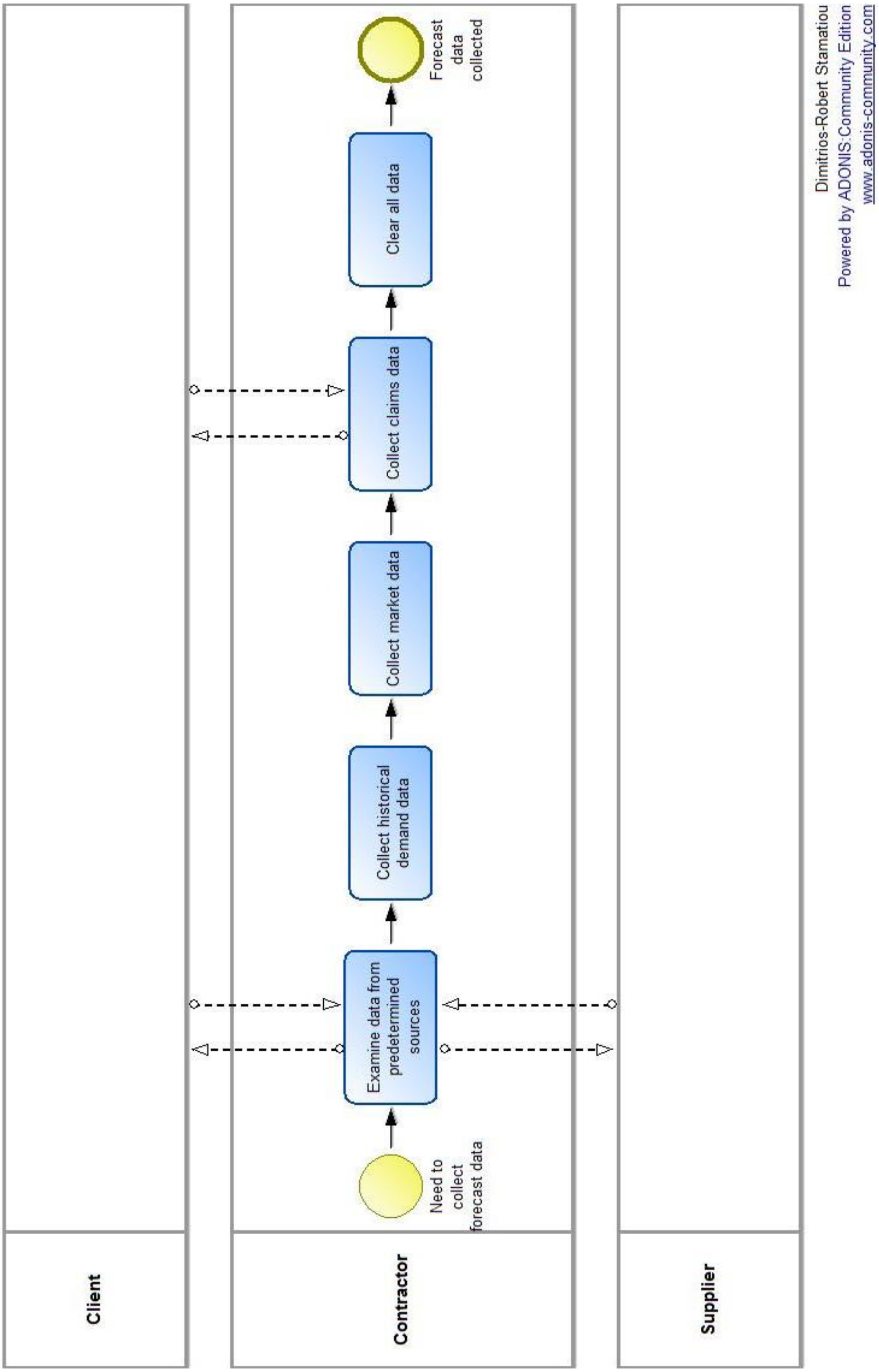

Figure 71: Forecast input data collection

The second operational process is “Demand forecasting” (**Figure 72**) and relates to the actual forecasting process. Upon initiation, the contractor may select to either forecast demand for residential, industrial, commercial, public works and utilities, repair and maintenance, and backlog simultaneously or choose to focus on fewer demand types and ignore others. This is a strategic choice and the addition of backlog helps the contractor prioritise the projects in the portfolio (Romano, Grimaldi and Colasuonno 2016). The first five demand types follow the division of project types as described by Fan et al. (2007) and backlog refers to demand for work package completion. It is placed in the forecast process because it is work in progress that occupies staff work-hours. Work-hours are proposed as the capacity measure in construction. The reasoning behind this proposal is that contractors often outsource a large amount of work to subcontractors, meaning that they merely handle contracts in these cases. Before new projects are undertaken, the contractor should check the capacity of the project management department. Back to the process, when selecting the industrial, commercial or residential demand forecasts, the tasks executed are ‘Select industrial demand forecast factors to use’, ‘Select commercial demand forecast factors to use’ or ‘Select residential demand forecast factors to use’ respectively. Such demand factors were analysed in **Table 17** for each type of project. Rosen (1984) identified the stock of office space, the flow of new office construction, the vacancy rate, and the rent for office space as key variables that need to be forecasted for office space forecasts, but these factors could also be useful in industrial and residential forecasts. In all three cases the next task is to ‘Analyse real estate market conditions’, as Grenadier (1995) propounds, through communication with clients and suppliers. The real estate market can provide information that will prove vital to the formulation of correct biding strategies and identification of risks and opportunities that can be attributed to market cycles. Next, through the task ‘Select number of years to be analysed’ an attempt to select the correct amount of historical data and give the past figures a different weight according to their age, especially in turbulent times, must be made. When selecting the public works and utilities market, the task ‘Select public works demand forecast factors to use’ is executed, and the related factors can be seen in **Table 17**. Next, the contractor should carefully ‘Analyse government policies’. As Forbes et al. (2012) underline, the infrastructure sector forecast should be used with caution. Furthermore, the task ‘Identify risks related to government announcements’ aims to check for forecast risk of such projects without solely relying on political forecasts (Flyvbjerg and Holm 2005). When selecting the repair and maintenance projects and forecasting the backlog the tasks ‘Select maintenance demand forecast factors to use’ and ‘Projection of backlog’ are executed respectively. When selecting the impact factors to be analysed in all six cases, as Fan et al. (2010b) propose, the involvement of the subjective judgment of the forecaster is allowed, but with respect to theoretical evidence in order to avoid spurious results. All paths merge to the next task, ‘Select forecast method’, and follow a common path. Different forecasting methods may be more suitable to specific data amounts and may range from data driven quantitative methods to soft qualitative such as the Box-Jenkins and Delphi methods accordingly. After the most suitable method is selected, the task ‘Perform forecasts for selected demand scenarios’ is executed. Additionally, during forecasting, land availability must be taken into consideration as a constraint that is either imposed by local authorities or the real estate market (Dong et al. 2009). Forecasts should include a variety of scenarios and the task ‘Determine forecast scenario to be adopted’ aims at the selection of the most suitable one according to subjective judgement by company experts. Next, through the ‘Determine acceptable error margin’ task the acceptable statistical error margins are determined. These margins work as a signalling device that warns about deviations on time.

It is thus important that they are not too small or too large; 15-20% should suffice. The selected forecast and its parameters should then be shared to key suppliers through the ‘Disclose forecast’ task in order to assist their strategic cooperation, receive feedback and reduce costs created by unexpected surges in demand. It is important to ‘Monitor actual demand’ and compare it with the forecasted demand. In case the actual demand is within accepted error margins, the process ends. In case the actual demand is outside the accepted error margins, first the task ‘Trace errors in forecast’ attempts to identify the root cause of the errors in order to avoid them in future forecasts and then the process loops back to the very beginning.

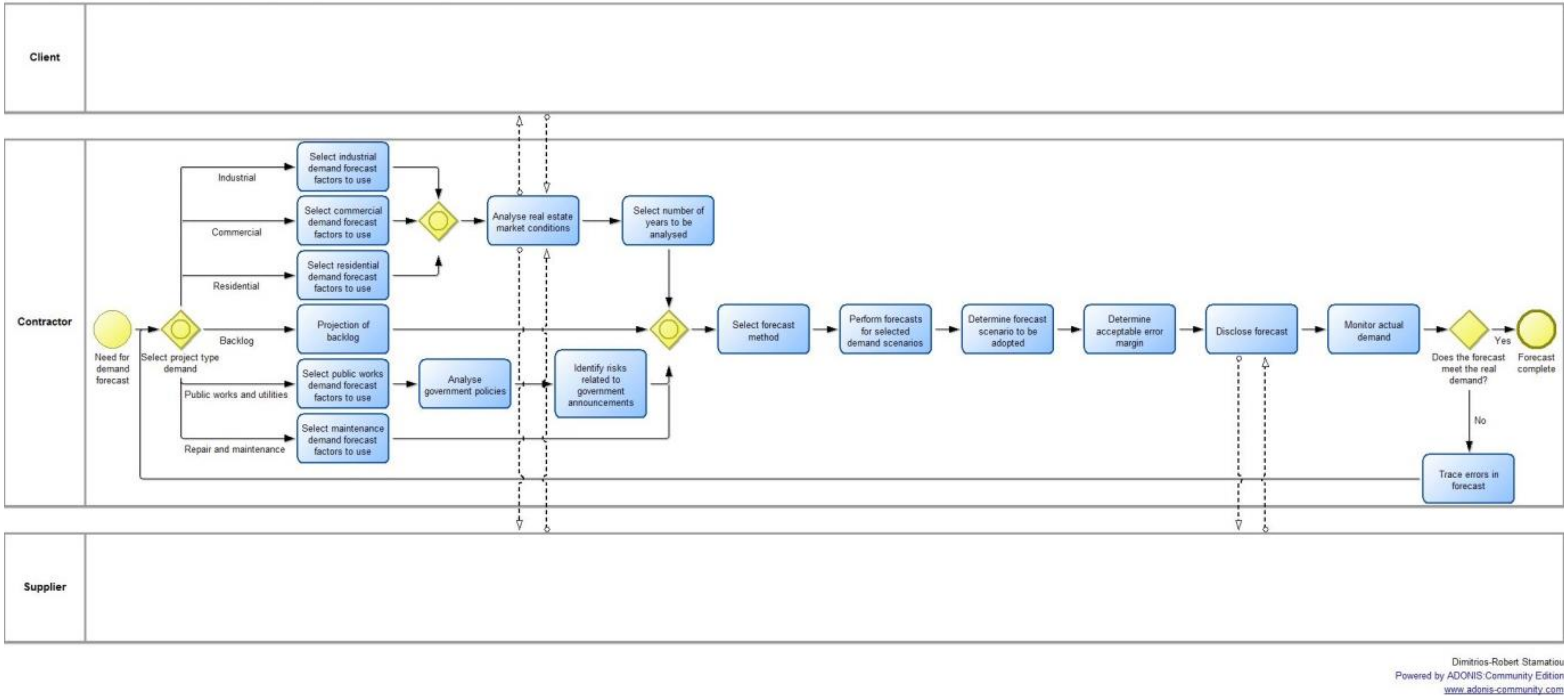

Figure 72: Demand forecasting

The third operational process is “Synchronise demand forecast with construction, supply, and logistics” (**Figure 73**) and relates to the transformation of the forecast into a plan to meet the forecasted demand (Croxton et al. 2002). The first task is to “Compare forecast with construction capacity” and identify if there are any shortcomings in capacity that need to be addressed or excess capacity that has to be managed (this usually relates to staff hiring/firing). Next, the contractor must ‘Examine possible limitations’ to the execution of the demand plan. These limitations may be imposed by internal factors, such as finances or inventory, or external factors, such as supplier capacities. The forecasts are estimations with an error range, so the contractor must ‘Determine confidence intervals for forecasts’ and communicate them to key suppliers to incorporate them in their forecasts. Next, the contractor must ‘Develop aggregate demand execution plan’, that will incorporate the demand levels that have been selected to be serviced, and share this information with key suppliers. Furthermore, the contractor must ‘Balance risks with financial constraints’ while satisfying the available demand. This task includes decisions on how to effectively allocate resources, mainly financial resources, and is heavily influenced by the type of clients in the market. Finally, the contractor must ‘Calculate capacity requirements for undertaking of new project types’. Suppliers play a critical role in the decision of a contractor to switch between project types in focus because of their high specialisation.

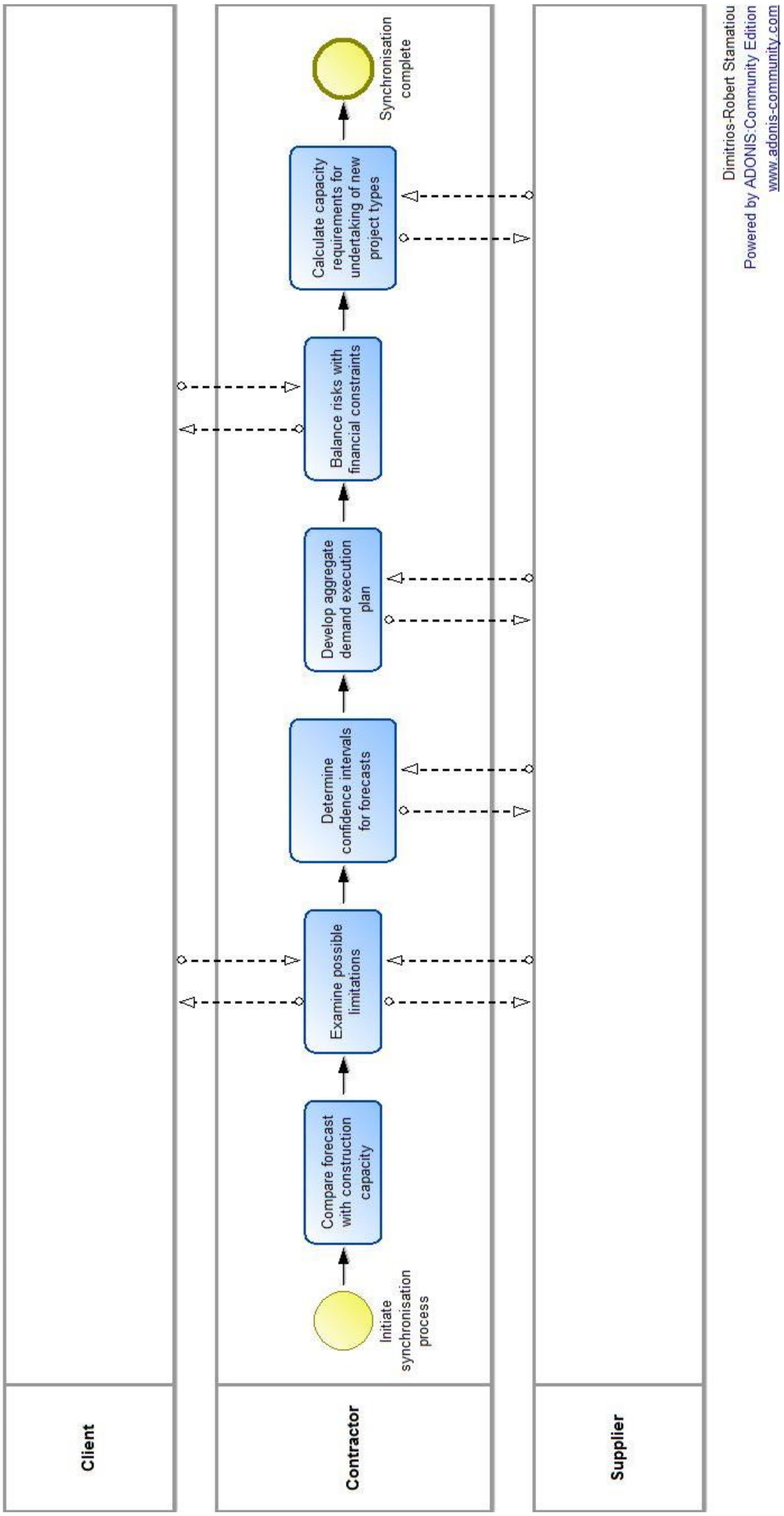

Figure 73: Synchronise demand forecast with construction, supply, and logistics

The fourth operational process is “Demand variability reduction and/or flexibility increase” (**Figure 74**) and aims at minimising demand variability that can be controlled by the contractor and increasing flexibility in the case of variability that cannot be controlled by the contractor. As Towill and McCullen (1999) state: “*the supply chain which best succeeds in reducing uncertainty and variability is likely to be most successful in improving its competitive position*”. Variability is not always obvious in the construction industry due to the construction lags and contractors may find themselves oblivious to demand changes because of their long lasting production schedules. As in manufacturing, it is less costly to reduce variability than to increase flexibility (Croxton et al. 2002), thus making variability reduction the first step in the process. The first task is to ‘Identify main variability sources’, for example tender prices and real estate pricings. Variability could be due to internal sources such as mismatches between forecasted demand and tender pricings, so the contractor must ‘Reduce variability inside company’. The next step would be to ‘Reduce variability along the supply chain’ by communicating with clients in order to monitor real estate prices or other sources of variability and making informed decisions on demand satisfaction. The last task of the variability reduction branch is to ‘Check if variability reduction was successful’. If the answer is positive, the process ends, if not, a decision has to be made: ‘Determine choice of further variability reduction or flexibility increase’. In the first case, the process loops back to the first variability reduction task, whereas in the second case, the flexibility increase branch is initiated through the ‘Determine level of required flexibility’ task execution. Increasing flexibility is costly, thus the level of increase must be carefully selected and the contractor’s managers must make sure not to miss any opportunities for flexibility increase that may come their way. Identification of bottlenecks and pinch points and development of cost-effective solutions are required to increase flexibility (Croxton et al. 2002). Next, the contractor must identify ways to ‘Increase flexibility inside company’ before contacting suppliers in order to ‘Increase flexibility along the supply chain’. The fact that most suppliers are SMEs and only hold a small capital with which to increase their flexibility levels makes this task very difficult to produce tangible results in construction supply chains. Finally, the task ‘Check if flexibility increase was successful’ is executed. If flexibility increase was successful, the process ends at this point, whereas if flexibility was not successfully increased, the process loops back to the ‘Determine choice of further variability reduction or flexibility increase’ with the same options available as previously. Interviews showed that, in the long-term, it is easier for contractors to increase their flexibility than to reduce their demand variability.

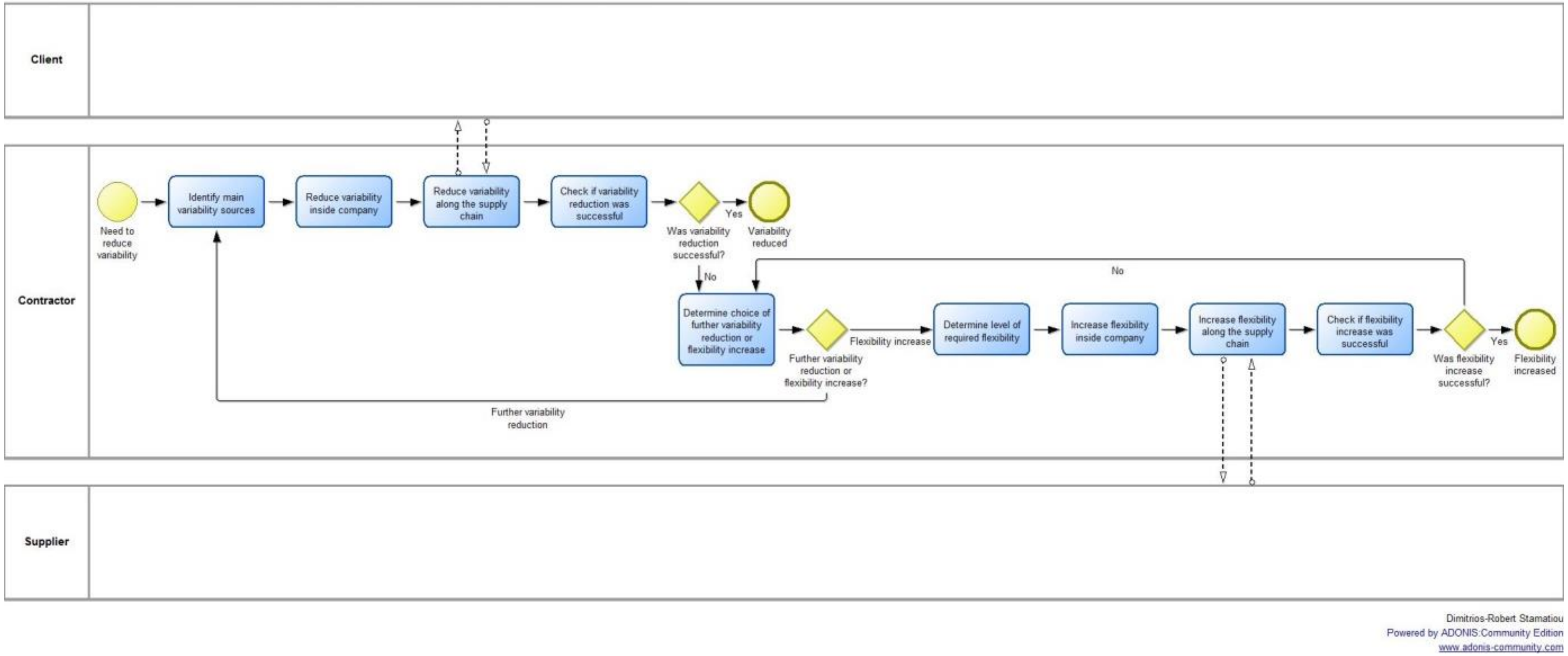

Figure 74: Demand variability reduction and/or flexibility increase

The last operational process is “Demand management performance measurement” (**Figure 75**). It can be executed for either previous operational process independently or collectively. The first task is to ‘Record and classify demand management process data’ which aims at monitoring process execution and collecting the relative data generated. Data is generated during both the execution and the result of each process and underperforming or overachieving operations can be recognised through this task. Next, the task ‘Monitor demand management performance indicators’ uses the data collected previously to compare with the performance indicators set at the strategic level. Since demand forecasting is the main target of the whole function, the task ‘Detect and analyse forecasting errors’ is dedicated to identifying the occurrence and sources of forecasting errors, their analysis and the lessons learned from these errors. This is very important because chronic forecasting errors can take their toll on the company’s survival. Next, the ‘Draft cost and profitability reports’ task is based on the financial indicators recorded and aims at identifying the costs and the profitability that have been incurred by the execution of the entire demand management function. Finally, the task ‘Determine performance improvement objectives’ is executed, aiming to capitalise the acquired knowledge for improving performance in future projects. These objectives can be shared with other key parties of the supply chain.

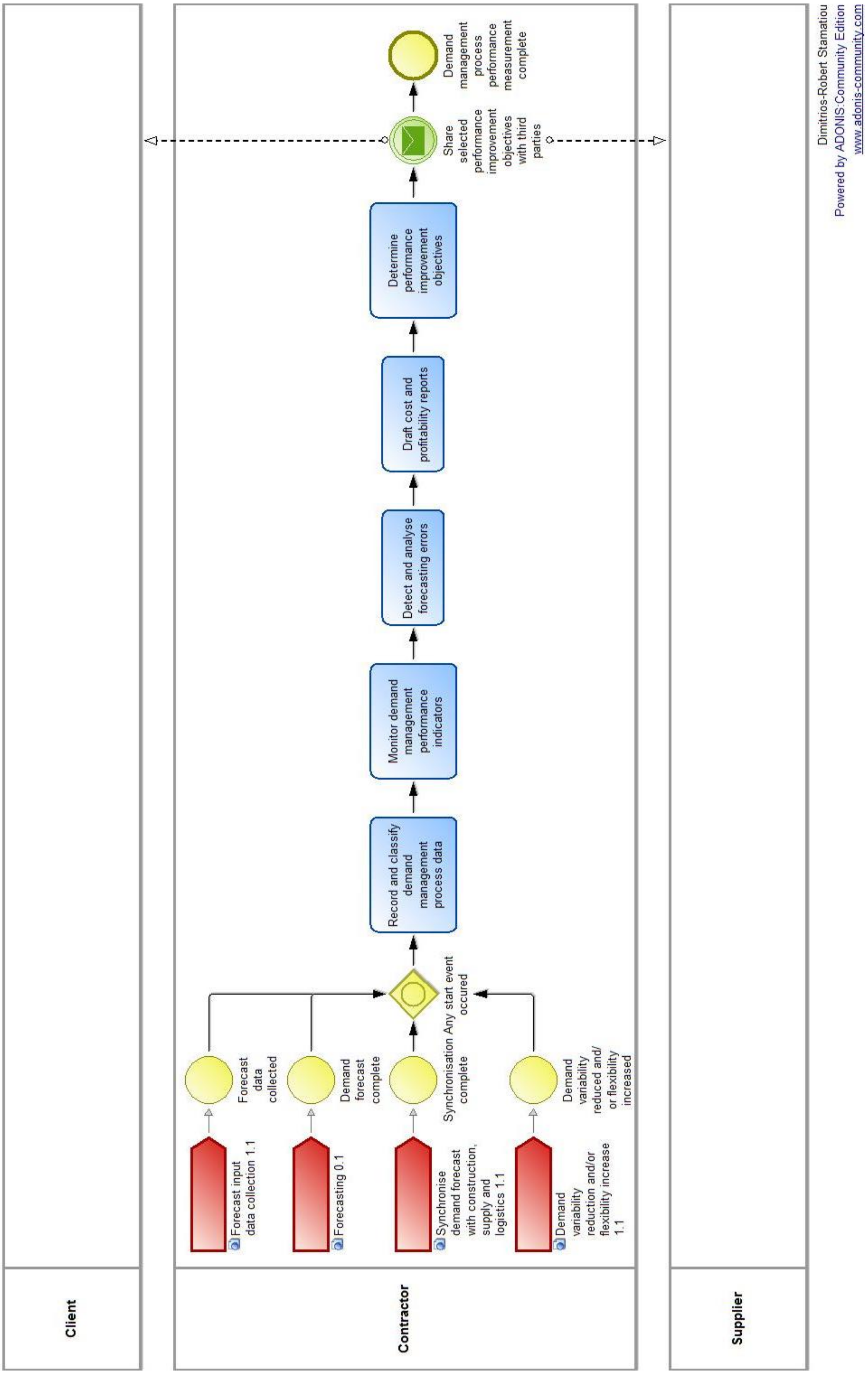

Figure 75: Demand management performance measurement

4.8. Work package management

4.8.1. Analysis of work package management

Because of the high complexity of a construction project it is broken down to smaller, autonomous but interrelated parts named work packages. Work packages are a general expression that represent a well-defined scope of work ending in a deliverable product or part of it (Li, Moselhi and Alkass 2006). Kim and Ibbs (1995) support that "*It is in these work packages that crews arrange construction equipment and assigned responsibilities are defined*". Work package management is more than a system that breaks down construction work, it is a planning activity that requires a high level of understanding for all project parameters (Kim and Ibbs 1995). The flow of work packages, that includes data on crew, product, work method, design information, and equipment, consists work flow in lean construction literature (Sacks 2016). Goodman and Ignacio (1999) identified poor integration between engineering, construction, and procurement disciplines as one of the main problems in work package management and Gibson Jr. et al. (2006) attributed this problem to the delayed involvement of project participants during the early project phases. Work packages are graded from generic to specific as follows: Construction Work Packages (CWPs), Engineering Work Packages (EWPs) and Installation Work Packages (IWPs), but in this work, the term work package refers to all of the grades collectively.

There are a few definitions available in the literature for work packages, the most prominent being the Project Management Institute's (PMI). According to the PERT Coordinating Group (1963), a work package is defined as "*the work required to complete a specific job or process, such as a report, a design, a documentation requirement or portion thereof, a piece of hardware, or a service*". The Project Management Institute (2013) uses the following definition: "*a work package is a deliverable at the lowest level of the WBS*". This means that the sum of the work packages constitute the work breakdown structure (WBS) and contains each specific element's cost and time forecasts. The PMI definition, despite its wide acceptance, does not provide any merit for the supply chain view of the work packages. Other definitions include: "*a quantity of a particular type of work at a specific location to be carried out by a specific work squad*" (Birrell (1980) as seen in Huang et al. (1992)) and "*A work package defines a definite amount of similar work to be done (or a set of tasks) often in a well-defined area, using specific design information, material, labor, and equipment, and with prerequisite work completed*" (Choo et al. 1999). The last definition is more production oriented than the rest and is more fitting to the work herein. A work package contains information regarding many aspects, such as the following listed by Gardner (2006): estimating, field engineering, project controls, construction, safety, document control, project planning, work package development team, construction crew, and special instructions. In their work Ponticelli et al. (2015) cited CII IR 272-2 (2013) for the description of the work packaging process as: "*any method of organizing work execution process within the scope of a construction project*". According to Gardner (2006) the ideal work package is small enough to provide rapid feedback to the work crews and big enough to provide a sense of accomplishment without being unmanageable. The dependencies between work packages and each work package's scope have been determined through the work structuring process and thus the coordination requirements between project participants should be included (Mitropoulos and Sanchez 2016). Despite the different systems used by organisations, information in work packages is standardised and relates to work-to-be-done, people and equipment assigned for specific days or hours, and materials needed (Choo et al. 1999). Sacks (2016) adds product, work method, design and equipment information to this list.

Huang et al. (1992) had identified trends, both in literature and in practice, that the CPM/PERT network analysis technique cannot address construction site management needs adequately. Koskela and Howell (2002) came to the same realisation and further add that Earned Value Management (EVM) along with CPM/PERT have failed to stabilise on site workflow. Thomas et al. (2003) studied labour inefficiencies and concluded that over 50% of them were attributed to poor work flow management. Work flow is defined by Huang et al. (1992) as "*the trade sequence of the same work type and similar productivity through work locations on the job over time*". Sacks (2016) supports that work flow in lean construction is synonymous with work package flow. Work structuring is the method used for work package development and is traditionally divided based on work trades. It may be performed by the project owner and their consultant, or the construction manager, or the general contractor during the procurement phase (Mitropoulos and Sanchez 2016). These work packages may be further broken down by the general contractor and assigned to subcontractors in part or in whole (Vidalakis, Tookey and Sommerville 2011). For example, Gardner (2006) noted that "*Engineering work packages (EWP) are frequently too large for effective management and control; their execution can last several months to over a year*". This practice is necessary for the reduction of complexity and size of the tasks into manageable pieces and to take advantage of specialised knowledge and resources (Mitropoulos and Sanchez 2016). Formoso and Isatto (2009) underline that the current practice of subcontracting requires additional coordination efforts. These additional efforts carry additional coordination costs and so do the production tasks (Tsao et al. 2004). There are three types of dependencies in work package management according to Crowston (1991): flow dependencies between sequential activities, a set of tasks that use common resources, and dependencies among tasks and subtasks. Three coordination challenges must be met in such dependencies, as highlighted by Mitropoulos and Sanchez (2016): the output of one task must be available at the time it is needed by the other task, the output must be of adequate quality, and the output must be available at the right place. Lack of coordination usually leads to quality issues that have to be resolved at a later stage of the project. The resolution of such problems is usually crafted on site through the execution of rework in 'informal work packages' that are not included in the planned schedule (Fireman, Formoso and Isatto 2013). The fact that these work packages have not been officially planned increases the level of uncertainty both during their execution and the execution planned work packages that face resource stagnation (Fireman, Formoso and Isatto 2013).

The nature of construction projects, more specifically their long duration and the volatile environment, creates a high level of uncertainty. This combination of factors leads to uncertainty along the project delivery process and its execution operations (Grau et al. 2014). This uncertainty may lead to variability in the work execution. Variability affects costs and durations of work packages, most likely inflating planned values (Boskers and AbouRizk 2005). Vidalakis et al. (2013) identified in their study that the main causes of additional costs in projects are unavailability of materials and unreliable deliveries that require the adoption of express deliveries. Dey et al. (1996) highlight that such uncertainties may have a large impact on projects even altering project scope during the execution phase. Uncertainty in construction can be attributed to factors such as design, materials and equipment availability, contractor ability, climatic environment, the economic and political environment, and statutory regulations which are all magnified by the size, complexity, level of involvement of external agencies, degree of impact of environmental issues level of impact of international trading conditions and currency fluctuations, unknown levels of inflation for long-term projects, and complexity of financing of the project (Dey, Tabucanon and Ogunlana 1994).

Work package management has two discrete steps, planning and execution. Zwikael (2009) highlighted the impact of sixteen planning processes (including activity definition, project plan development, organisational planning, activity sequencing, resource planning, risk management, and quality planning) on project success. Grau et al. (2014) support that the definition of work packages at the task level, and then further by unique location sectors, is a prerequisite for both planning and monitoring the work flows. Meredith and Mantel (2009) describe planning as a compilation of directions that "*tell the project team exactly what must be done, when it must be done and what resources to use in order to produce the deliverables of the project successfully*". Additionally, during the planning phase, there is a tuple of constraints, categorised into constraints on contract, engineering, material, labour, equipment, and prerequisite work, that need to be satisfied in order to successfully carry out the work package (Choo et al. 1999). During the planning phase, special care must be given to the 80/20 principle, i.e. the 20% of work packages that cost 80% of the project. Binninger et al. (2016) support that due to the insufficiency of prior experience in planning complex and interdependent execution processes such processes should be supported with calculations and technical systems but not restricted to such tools. One of the basic requirements for the planning phase is the levelling of work packages that offers steady utilisation of resources and constant production rhythm (Binninger et al. 2016). On the execution phase, in current practices activities have to be levelled. Current levelling practices include consolidating the separate working areas, dividing the work, optimisation of individual work steps and work content, and levelling of teams (Binninger et al. 2016). This practice mainly involves defining Takt units and matching workload to the available workforce (Binninger et al. 2016). The nature of Takt units may differ depending on manager experience or project needs and may relate to surface areas or time. Takt time planning aims to increase productivity through waste reduction by optimising work packages and team sizes to meet the required productivity (Vatne and Drevland 2016). In the case of Takt time planning, the production plan consists of work packages that can be completed in the set time frame. This allows for good coordination with the Last Planner system used in lean construction and is especially effective in projects with a rate of repetitive work packages (Vatne and Drevland 2016).

There are many problems regarding both planning and execution of work packages recorded in current literature. In the planning phase, the lack of hands-on experience makes clearly defining the full scope of the work package, assessing its' real nature, the matching methods, and the required capacity of resources an arduous task (Choo et al. 1999). Ponticelli's et al. (2015) study of the contemporary literature identified poor integration between the engineering, construction, and procurement disciplines as one of the main problems faced in work package management and attributed it to "*the delayed involvement of project participants during the initial project phases*" (Gibson et al. (2006) as seen in Ponticelli et al. (2015)). The interests of all parties do not coincide. For example, Choo et al. (1999) identified that general contractors aim at scheduling sequences of varying work packages whereas, in contrast, specialty contractors attempt to schedule a flow of similar work. Poor communication and coordination means that it is hard to identify work crews that have aberrated from the set schedule until it is too late to restore the lost time (Gardner 2006). In multi-trade work packages such issues get more complicated due to following factors: owners may require the break-up of such work packages into smaller ones, management fees for coordination and additional costs incurred by sub-subcontracting, and coordination burden for the general contractors in the case of unfit subcontractor managers (Mitropoulos and Sanchez 2016). The fact that the optimisation of work packages is left to subcontractors reduces the general contractor's ability to influence optimisation according to the specific needs of the project (Binninger et al. 2016). In many cases, construction managers do not identify problems in work packages until they are notified by the work crews (Gardner 2006) which causes many disruptions to the project. Ibrahim et al. (2009) attributed this phenomenon to the involvement of human judgement, high costs, and infrequency of data collection in traditional methods that prevent managers from handling timely and accurate control data. According to Vrijhoef and Koskela (2000) one of the main sources of problems in construction projects can be traced to the interfaces between different parties or departments of the contractor. Bad coordination and communication leads to two major problems in the work field according to Leão et al. (2014): the creation of 'informal work packages' (execution of work that was not in the short-term plan that changes production order) and the execution of new work packages that are not in the production plan due to the arrival of new work crews (who turned up at the site ahead of schedule). Additionally, quality related issues are reported in projects because of the independent execution of production and quality control. Fireman, Formoso and Isatto (2013) attributed 'unfinished work' type of waste to this lack of coordination and Leão et al. (2014) observed that over 50% of this waste is recurrent. The effects of the fragmentation of the construction supply chain on the production process of the project were highlighted by Draper and Martinez (2002). The production plan passes the project requirements through the supply chain and this causes conflict of interests among the project parties. Binninger et al. (2016) described the machine and equipment use as 'below capacity' and human resources use as having 'inconsistent rhythm' due to poor planning that creates high demand peaks for the subcontractors, and the bullwhip effect along the entire supply chain.

Early work packaging is a proposed solution to many of the current problems faced by work package management. Benefits of early work packaging and involvement of other supply chain parties during their development include the following according to Gardner (2006): effective framing of cost elements, integrated estimating, effective work face planning, proactive approach to execution, reduced changes during execution, easy change management, resolution of Requests for Information (RFIs) prior to construction, safety pre-planning, quality pre-planning, spin-offs including better integration and teamwork during the development of construction work packages as the team works to package collaboratively, rapid learning curve maturity, and short duration providing rapid feedback on probability of meeting schedules and early opportunities to take remedial action. Other benefits of such practices are highlighted by Alleman et al. (2017) as: expediting the project schedule, mitigating risk, reducing project costs, minimising impacts to the public, and matching funds to meet project cash flows. One of the tools developed that adopts and attempts to capitalise on the benefits of early work packaging is the Advanced Work Packaging (AWP) methodology developed by the Construction Industry Institute (2013). The AWP methodology is comprised of the following three stages: 1) 'Preliminary Planning' consists of the project breakdown into Construction Work Packages (CWPs) defining the logical and manageable division of work within the construction scope; 2) 'Detailed Engineering' has an engineering and procurement perspective and aims at the detailed specification of Engineering Work Packages through the breakout of construction work hours and resource loading of the next stage's schedule; 3) 'Construction' consists of the detailed planning and execution of Installation Work Packages (IWPs) containing all the required support documents for the safe and efficient installation of a specific system (Ponticelli, O'Brien and Leite 2015). Case studies performed by Ponticelli et al. (2015) contrasted projects that adopted Advanced Work Packaging with projects that used traditional methods and found that the prior projects performed better than the latter in terms of cost, schedule, quality, and safety performance but required full support by all hierarchical levels of the parties involved in the project in order to be effective.

The literature documents a few efforts to optimise work package management. Dey et al. (1996) used the 'Goal programming' technique, a multiple criteria decision-making technique, to plan projects in a hierarchical three level (project, work package and activity) model aiming to increase flexibility in the planning stage. In a similar spirit, Cheng and Tsai (2007) used 'Axiomatic Design' to develop "*a fast-track scheduling method for design-build project to decompose a project into work packages and further to determine the overlap relationships between work packages*". Ibrahim et al. (2009), Sacks et al. (2009) and Grau et al. (2014) developed tools based on BIM systems to support different features of work package management such as assessment, flow, monitoring and safety. Finally, Boskers and AbouRizk (2005) developed a simulation based-model for assessing uncertainty in long-term costs, durations and timing of work packages in capital infrastructure projects. Huang et al. (1992) analysed contemporary literature and identified that the work packaging concept is also applicable to other project functions such as improving cost visibility, integration of cost with schedule control, integration of engineering plans with construction plans, and integration of cost and schedule control on the job site.

4.8.2. Work package management process model

As in Kim and Ibbs (1995) the model presented in this section is created by identifying major decision variables that affect the work-packaging process and enriching the basic foundation with additional important tasks. The "Work package management" function is comprised of eight processes; four strategic and four operational (**Figure 76**). Work package management processes have been divided like this again in the literature by Kim and Ibbs (1995). The four strategic processes can be executed in parallel or sequentially depending on the organisational needs. The strategic processes are the following: "Determine work package management requirements", "Evaluate supply chain network", "Plan for work package completion" and "Develop project contingency management processes". Strategic processes may refer to a specific project or the entire project portfolio. Operational processes are executed sequentially, with the exception of the performance measurement related process that can be executed either sequentially or in parallel to the others. Operational processes focus on work packages of a single project and are the following: "Prepare and communicate work package", "Process work package", "Handle documentation" and "Carry out quality control activities and performance measurement". Li et al. (2006) developed a project database in their work to perform project control functions and found that the use of such systems can be efficient and, thus, they are endorsed in this dissertation.

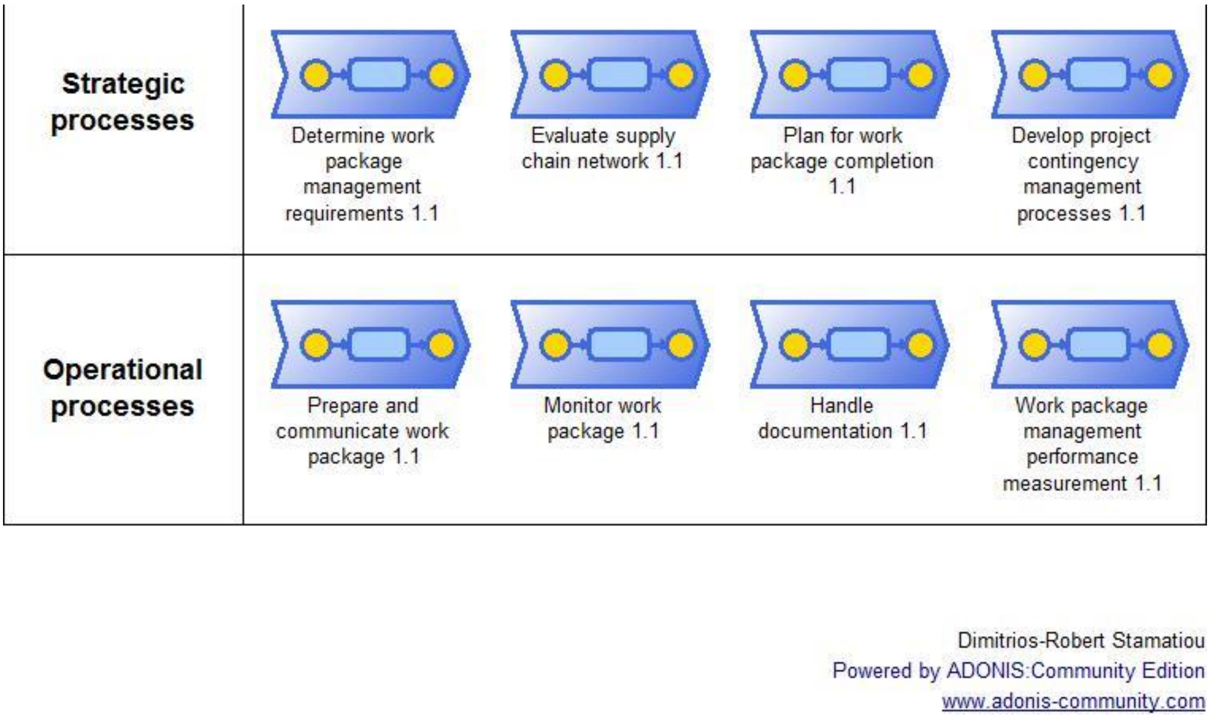

Figure 76: Work package management function tree

4.8.2.1. Strategic processes

The first strategic process is “Determine work package management requirements” (**Figure 77**) which aims to examine the internal and external requirements for the work package management function. The first task is to ‘Determine client requirements’ and is based on the client contract. Time, cost, quality and scope of each work package are all described in the contract. Next, the contractor should ‘Determine operational requirements’ that include number of work packages executed simultaneously, legislative restrictions and other such requirements. In addition, differences between peak and average workforce must be identified (Forbes et al. 2012). This task is followed by the ‘Determine factors that affect performance outcomes’ task which aims to identify factors such as weather, availability of resources, working conditions, labour ability and others described by Korde et al. (2005) that may be measured at the project, work package or activity level. Huang et al. (1992) underline the importance of the ‘Identify basic functional and process elements’ task for each work package in order to improve monitoring and management of the work packages. Finally, the ‘Create work package registry’ aims at creating a registry through which preparation of work packages for subcontracts, preparation of budgets and cost control is conducted (Cooke and Williams 2009).

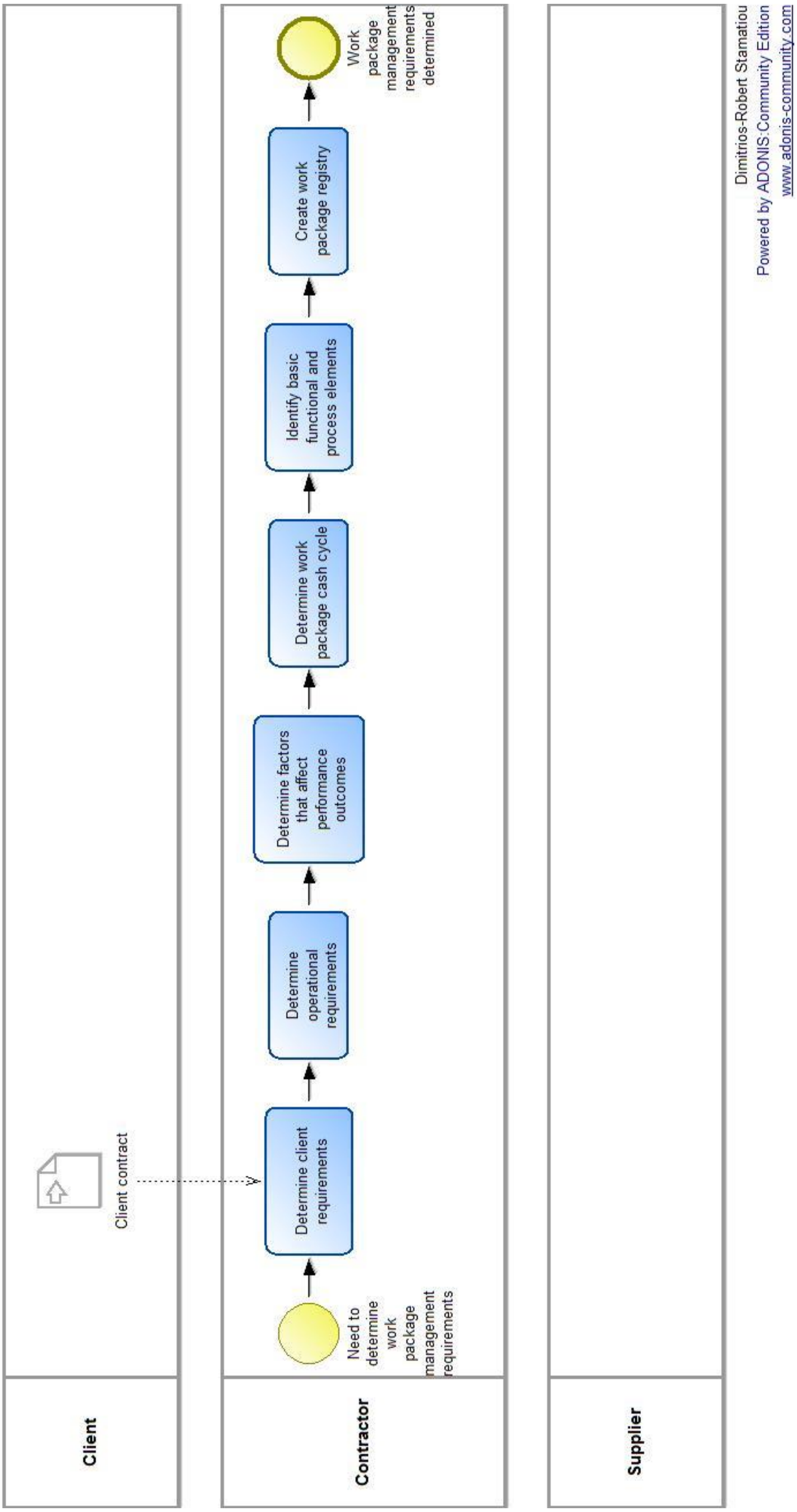

Figure 77: Determine work package management requirements

The second strategic process is “Evaluate supply chain network” (**Figure 78**) and aims to identify supply chain network issues that affect work package management. The first task for execution is the ‘Prioritise projects in the portfolio’ task that aims at classifying projects according to the severity of delays, the resources required for work package execution, the importance of the client relationship and other factors. Next, the execution of the ‘Identify project completion requirements’ task aims at analysing the WBS of each project and identifying common basic functions and processes that may lead to supply chains taking advantage of economies of scale. Huang et al. (1992) support that the creation of meta-WBS by merging different project types can prove beneficial. All construction supply chains operate under financial constraints, therefore it is important to ‘Examine project supply chain capabilities to complete work packages under financial constraints’ and evaluate alternatives in case financial risks are realised. Next, the ‘Determine construction units to be outsourced’ task aims at analysing work packages and identifying activities or entire work packages that should be outsourced for optimal execution. This leads to the next, final, task of the process, ‘Determine location of suppliers’ that aims at identifying costs that occur due to long distance transportation of materials or staff, high specialisation of services or other factors that may affect the selection of a subcontractor.

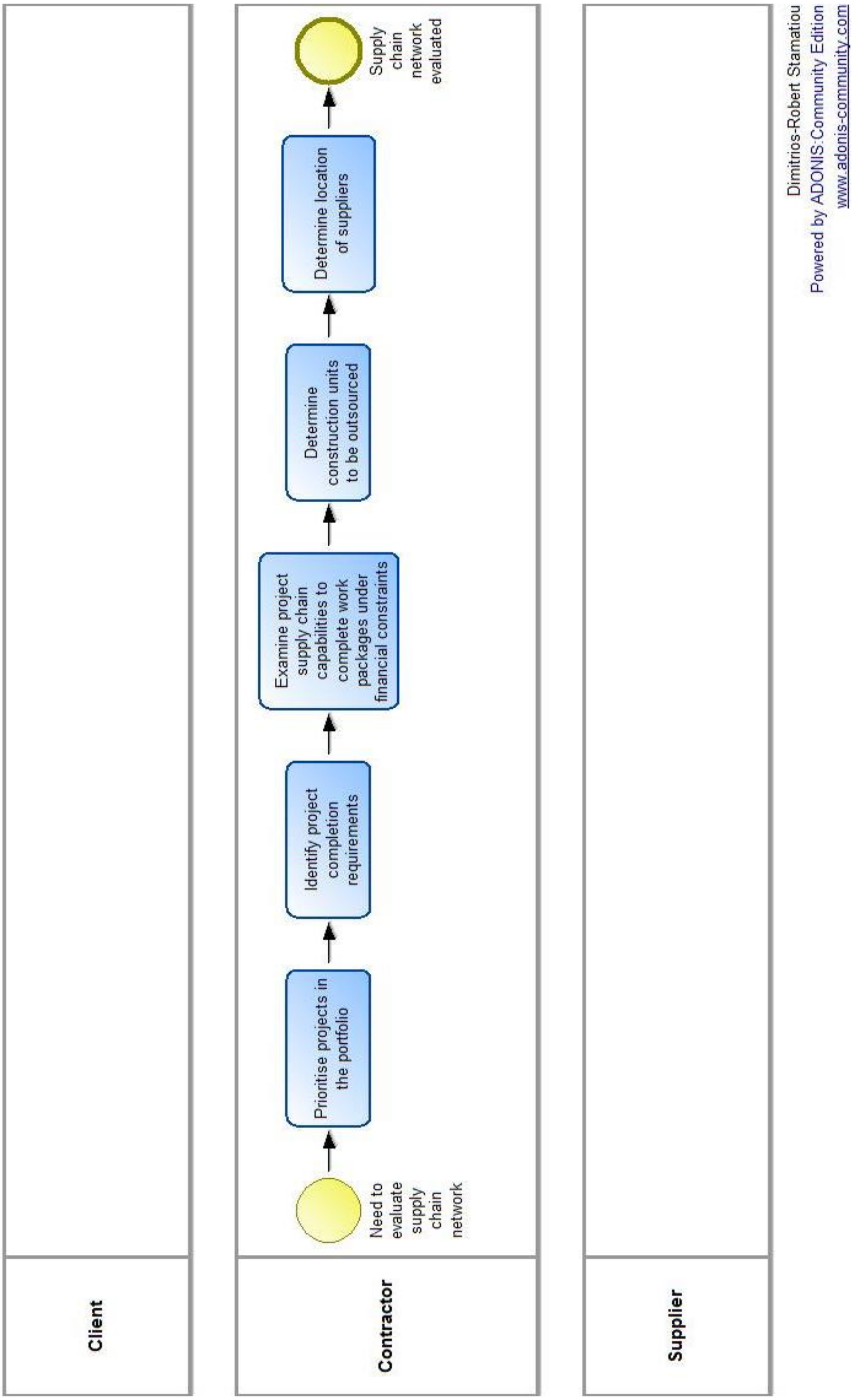

Figure 78: Evaluate supply chain network

The third strategic process is “Plan for work package completion” (**Figure 79**) and it includes all necessary planning tasks for the execution of the work packages of multiple projects. The first task is to ‘Establish LPS lookahead schedule’. The Last Planner lookahead plan considers the tasks that are scheduled for a specific mid-term time period and identifies the prerequisites for the execution of those tasks in the desired period (Ballard 1997). Next, the contractor has to ‘Classify work packages’ into strategic, management, or operational, according to Huang et al. (1992), in order to allow for better prioritising. This is then followed by the ‘Determine cost model factor’ task that identifies the value ratio of cost-significant work packages to the total project (Horner and Zakieh 1996). This indicator is important in order to plan the required capital availability for the seamless execution of these specific work packages. The task ‘Determine trade work sequence, location and flow’ aims at the creation of a mid-term work plan that is shared with suppliers in order to inform them of the upcoming work. Suppliers may then determine their own detailed work flow plans (Huang, Ibbs and Yamazaki 1992). It is important, especially in cases of work crews that have to handle supplies that are not their responsibility, to ‘Plan resource availability’ in advance. This is critical in order to get work done on time and items such as drawings, materials, equipment and tools, available work space, and method specifications are rarely depicted in the CPM plan that is shared amongst partners (Choo et al. 1999). Next, through the task ‘Determine terms of payment’, the contractor identifies the terms of payment of each planned work package. These terms are usually described in the contract and depending on the cost of each work package may be a lump sum paid upon work package completion, gradual capital releases during the execution of the work package, or similar arrangements that concern a group of work packages. The advent of powerful IT systems has allowed the development of sophisticated software that can support the planning and monitoring of work package execution. The task ‘Determine progress monitoring level of detail’ aims at identifying the appropriate level of detail at which progress will be assessed through such tools (Ibrahim et al. 2009). One of the major inefficiencies identified in the literature is the separate planning of production and quality control. Thus, the task ‘Integrate production and quality control’ that aims at the integration of these two operations aims to reduce informal packages and relative waste (Leão, Formoso and Isatto 2014). Finally, through the ‘Assess role of technology’ task the contractor keeps an eye on the effects of technological developments on the planed work packages.

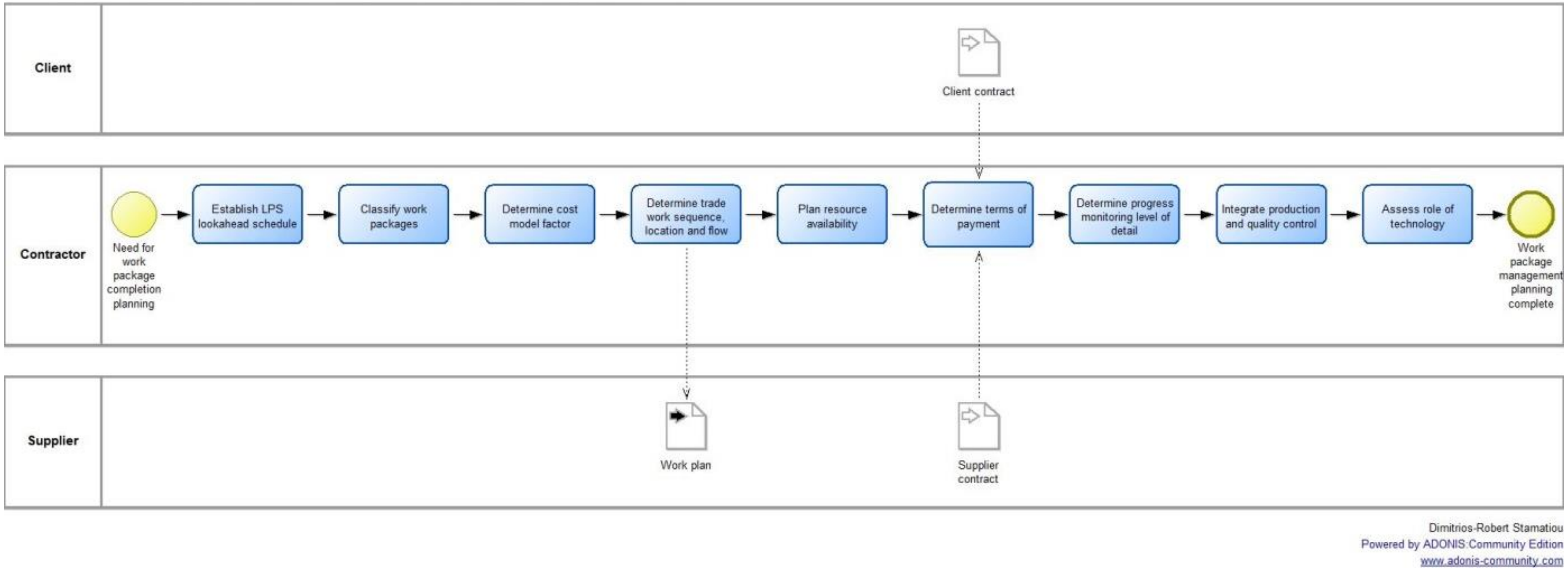

Figure 79: Plan for work package completion

The last strategic process is “Develop project contingency management processes” (**Figure 81**) and relates to the proactive management of project specific risks. There are certain risks that are common across any project, but the particularities of each project may present management with a number of project specific risks. One of the most important risks to consider in any project is the risk of supply disruption (Croxton et al. 2002). The first task in this process is to ‘Analyse risks for total project scope through the WBS’. Dey et al. (1994) highlight that, by convention, risk analysis is performed at the project level and focuses on the effects of risk factors on project performance. They also make clear that this might be sufficient for a small project, but in case of a large and complex project such an approach will not suffice and a lower level of analysis may be required. The subsequent sub-process named ‘Analyse risks for each discrete work package’ (**Figure 80**) is based on the work presented by Dey et al. (1996) and consists of the following eight tasks: ‘Estimate base cost’, ‘Determine range estimate by activity analysis’, ‘Calculate expected cost’, ‘Calculate anticipated contingency’, ‘Determine work package overall risk’, ‘Calculate desired success percentage’, ‘Determine target cost’, and ‘Calculate total work package contingency’. The total risk of each work package is a very useful metric to support the decision of capital allocation by risk managers. Successful risk management at the project level is a major factor to the profitability of the project.

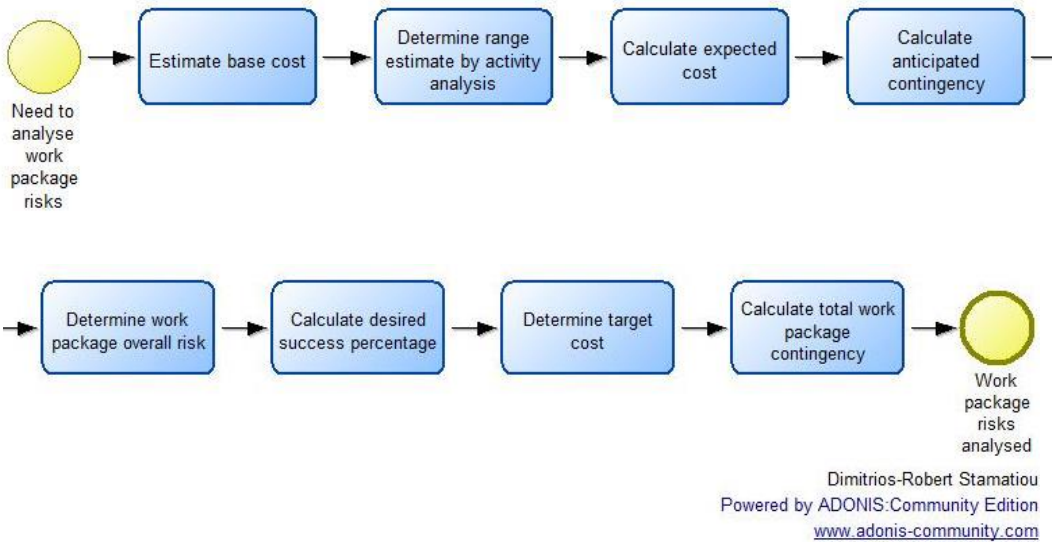

Figure 80: Analyse risks for each discrete work package

Back to the main process, the next task to be executed is ‘Rank work packages according to risk assessment’. This ranking may be shared amongst interested parties and receive input by more experienced staff belonging to other parties that are specialised at specific work packages. Next, the contractor must ‘Determine response processes’ and share them with the other parties in the project. In specific, the contractor may need the client’s approval for the adoption of the selected response processes that may affect critical parameters of the project, or supplier input related to the best possible management of the risk. Finally, the task ‘Update project risk catalogue’ is executed and the risk sheets are either saved in a database or are distributed on paper at the work site.

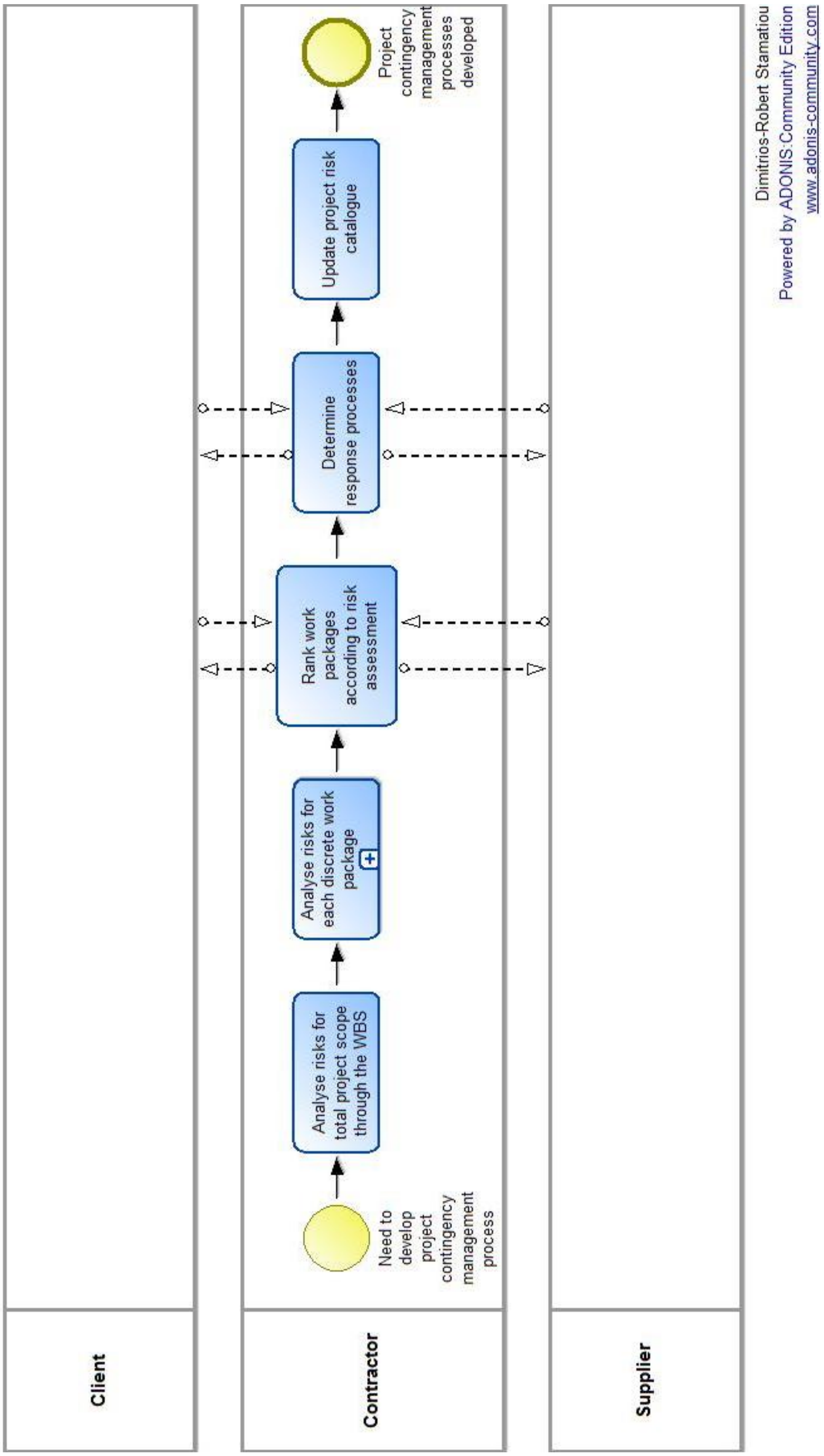

Figure 81: Develop project contingency management processes

4.8.2.2. Operational processes

The first operational process is “Prepare and communicate work package” (**Figure 82**) and aims to prepare the planned work packages for execution. The first task is to ‘Prepare weekly plan form LPS lookahead plan’. “*Weekly work planning is planning with the highest level of detail prior to having (skilled) laborers carry out the work*” (Choo et al. 1999). The lookahead plan contains an inventory of ready work from which the weekly work plan is formed (Leão, Formoso and Isatto 2014). Long-term work packages contain information on major work quantities, labour, material, and construction equipment, whereas the short-term plan is developed by refining the long-term plan based on input from the worksite (Kim and Ibbs 1995). Interviews revealed that this lookahead plan typically spans 2-3 weeks in the future and includes time schedules and work definitions. Next, the contractor should ‘Check resource availability’ prior to starting work (Choo et al. 1999) and make sure that suppliers can provide on time. Interviews showed that this task aims to ensure supplier flexibility and to check if this resource is to be used across projects or multiple work packages. This is followed by the ‘Filter work packages’ task that aims to avoid initiating work that cannot be executed according to the plan (Ballard 2000) in order to avoid repeated mobilisation and demobilisation of resources (Choo et al. 1999). This task could be supported effectively by an interface to a BIM model (Sacks, Treckmann and Rozenfeld 2009). Next, the contractor should ‘Satisfy all constraints’ before the work package is released for execution (Choo et al. 1999). Once all constraints have been satisfied the work package is ready for initiation and the task ‘Communicate work package initiation’ is executed and the production order is communicated to the suppliers. Interviews showed that the people responsible for the flow of this information are the superintendent and the supplier foreman.

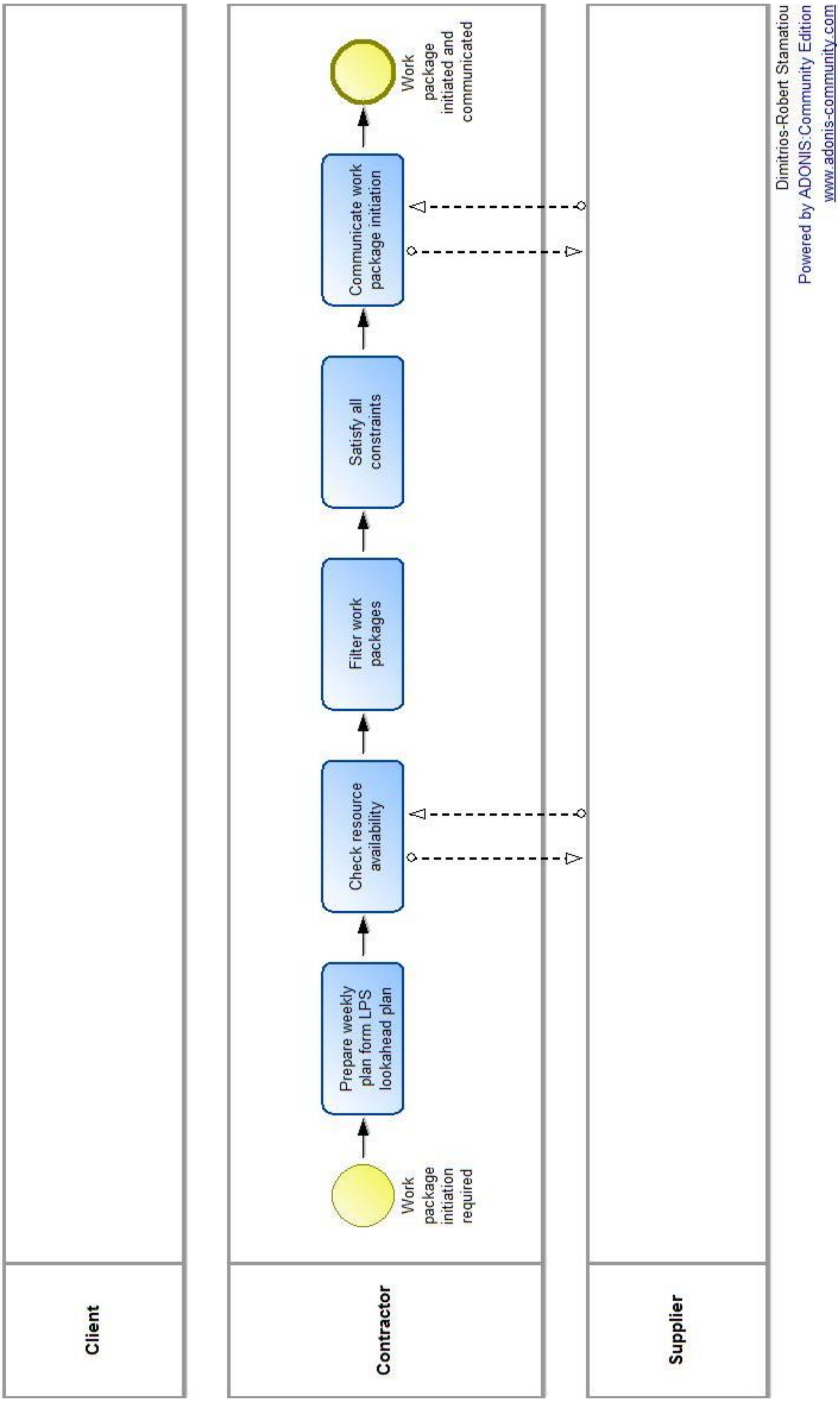

Figure 82: Prepare and communicate work package

The second operational process is “Monitor work package” (**Figure 83**) and includes tasks that are executed in order to monitor progress. The first task is to ‘Monitor EVA’. Baldwin and Bordoli (2014) prompt that the overall status of project or work package progress is measured in monetary terms by measuring the incurred costs and comparing them to the output at the time of measurement. Li et al. (2006) developed a system that can generate status reports at user selected dates based on the EVA data. Baldwin and Bordoli (2014) warn users of the following pitfalls related to the use of EVA: system requirements are not clearly identified and documented; progress is not monitored against updated schedules; construction work progress is incorrectly assessed; cost analysis is performed with inaccurately allocated cost data; lack of agreed understanding of what comprises the present value of the work; and failure to prepare a fully completed WBS integrated with the cost estimate and time schedule. Once work is carried out it is documented on timesheets (Choo et al. 1999). Despite the existence of the EVA tool, interviews indicated that none of the contractors made use of it and monitored work executed through project management software or through the bill of quantities signed off by the quantity surveyor. The next task, ‘Check timesheets’, includes the analysis of such documentation provided by subcontractors to the work actually recorded by the work site superintendents. This is followed by the ‘Perform quality control’ task, a task described as paramount in most interviews that includes quality assurance and is dictated by harsh contract clauses. Quality control is usually considered as the comparison between as-planned and as-is work, but Leão et al. (2014) add another dimension to quality control which is the creation of ‘informal work packages’ and is common practice in many projects. These ‘informal work packages’ are comprised of work that does not meet required quality standards. Leão et al. (2014) propose a process model that aims to abate this phenomenon. According to Leão et al. (2014), Sukster (2005) “*pointed out to the importance of look-ahead and short-term planning meetings for integrating task completion and quality control*”. When work packages have been completed, all parties gather to execute the ‘Work package sign off/handover’ task. This task was revealed in interviews with large contractors but was not mentioned by SME contractors. The contractor certifies that all work conducted by suppliers is as planned, suppliers sign the delivery of their work , and clients sign that work has been executed as expected. Winch (2001) reported that the architect and quantity surveyors are the ones implicated in this task on the client’s behalf. The next task, ‘Hold planning meetings’, is executed alongside the subcontractors in order to monitor the progress of both work package execution and quality control. Finally, the task ‘Enter work package details into log’ is executed and the log is shared with the client. Russell and Froese (1997) identified that management feedback and learning is lost in work sites because crew supervisors tend to discard weekly work plans once work has been executed. Gardner (2006) underline the need of a log that is comprised of details related to work packages and the related document control and such is the aim of the task proposed. In reality, according to the interviews, this task includes the logging of site log details and minutes held in planning meetings.

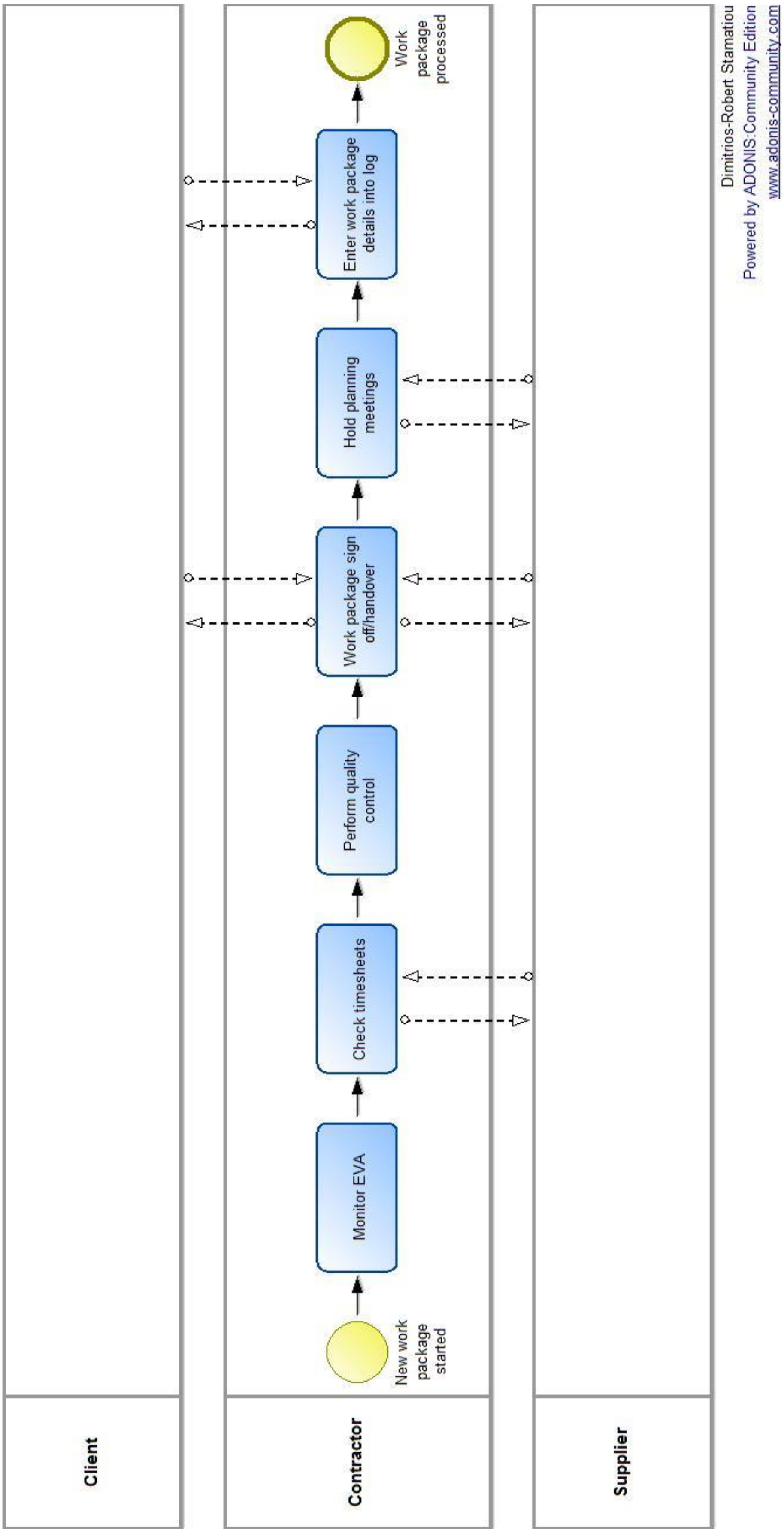

Figure 83: Monitor work package

The third operational process is “Handle documentation” (**Figure 84**) and its execution may last as long as the work package (plus some administration time) or may be repeated at a period of one Takt time. The first task is to ‘Issue preliminary document registry’ that lists all existing and expected documents for a work package (bill of quantities, designs, etc.). This task was revealed through interviews with large contractors. Then, the ‘Manage site records’ task is executed. During work package execution, a superintendent monitors all execution parameters and logs them on the work site diary. This information must be managed in order to identify problems in the execution, their source and the solution implemented. Site records play a very important role in the claims management process and their richness helps the contractor support the claims received or submitted. Interviews revealed that, depending on the project, records include documents such as quality control sheets, log books, pictures, time-lapses, monthly presentations, non-conforming reports, worker insurance, invoices, designs, third party liability insurance, agreements, specifications, public authority permits, and consignment notes. Next, through the ‘Manage quality control sheets’ task, quality sheets are classified; errors are identified and upon their correction are inserted in the deliverables documentation. After quality control sheets have been added to the document registry, the contractor executes the ‘Final document review’ task that includes the certification that all expected documents from the preliminary list are in place and lists all other documents produced during the work package execution. This task was identified through the interviews conducted with large contractors. Finally, the ‘Manage invoices’ task is executed, which includes the handling of outgoing and incoming invoices for work complete. Invoices may contain details of work executed and must be contrasted with the contract and other documents in order to receive or give out the payment. This task includes the cost control process. As cost control is handled differently depending on the size of the contractor, the size and complexity of the project, staff’s experience and skills, client requirements and supplier relationships, subprocesses related to cost control vary. Interviews revealed that invoices are handled at a monthly basis. A further analysis of the cost control process is beyond the scope of this dissertation.

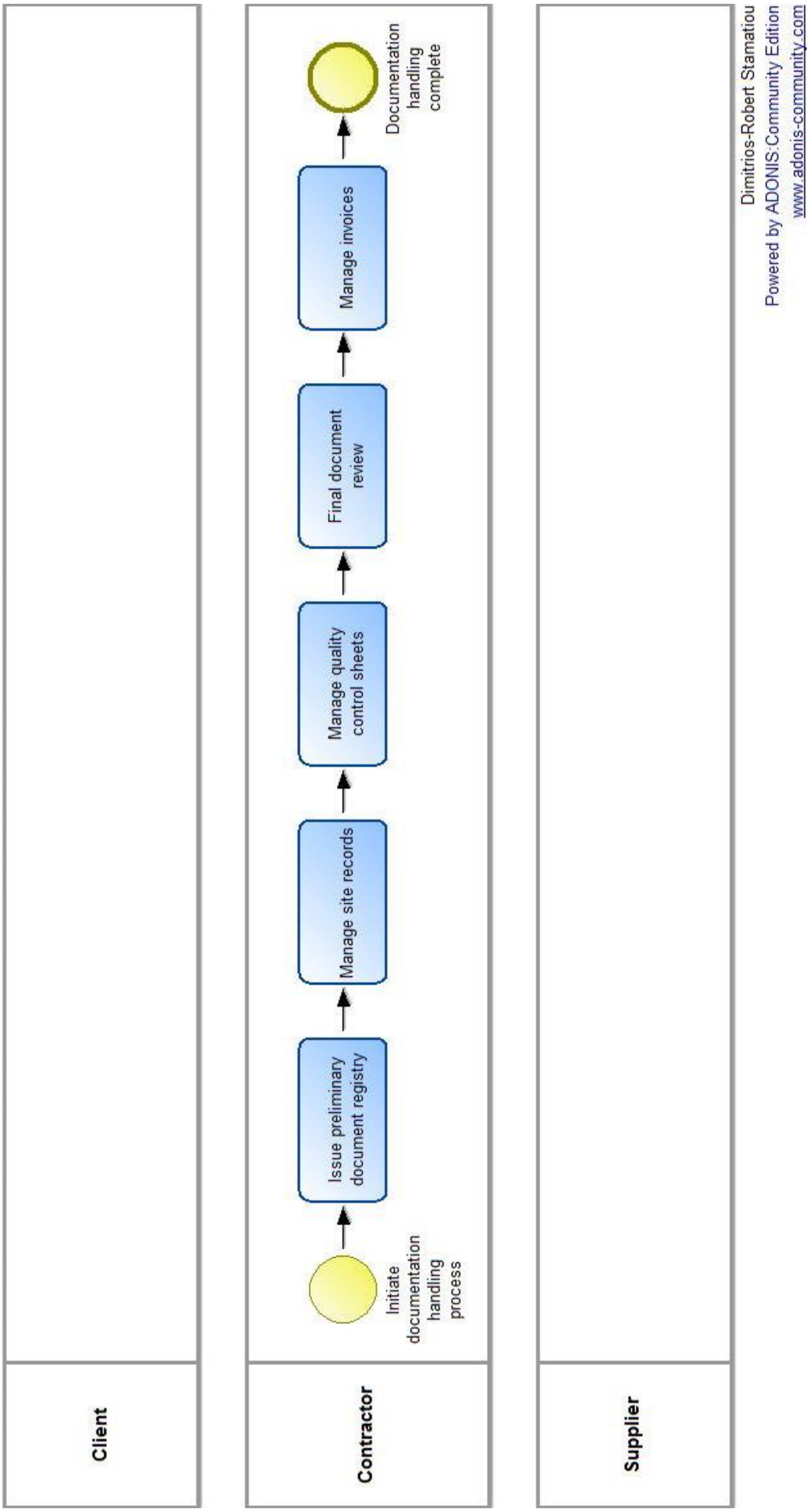

Figure 84: Handle documentation

The last operational process is “Work package management performance measurement” (**Figure 85**) and includes all tasks related to the process measurement of the work package management function. The first task is to ‘Record and classify data from work package management operations’. As Ibrahim et al. (2009) note, integrated monitoring and control requires collecting data for variables at the same level of detail. There are many levels that performance measurement can be performed. Korde et al. (2005) propose data collection and evaluation to be performed at three levels: project level, project participant level (group or trade level), and activity / work package level. Next, the task ‘Monitor work package management performance indicators’ includes analysing the data collected previously and the generation of useful indicators of process performance. The ‘Detect and analyse main problems in work packages’ task aims at identifying the main shortcomings during the execution of work packages and the directly related processes. Conclusions from this analysis could provide useful information during project execution or for new projects. Next, the ‘Draft cost and profitability reports’ is an important task that assists the decision making process both at portfolio and project level based on the performance-to-date analysis (Grau et al. 2014). Finally, the ‘Determine performance improvement objectives’ aims to identify opportunities for future improvement through the resolution of shortcomings. The contractor may select to share performance measurements or improvement objectives with key supply chain partners.

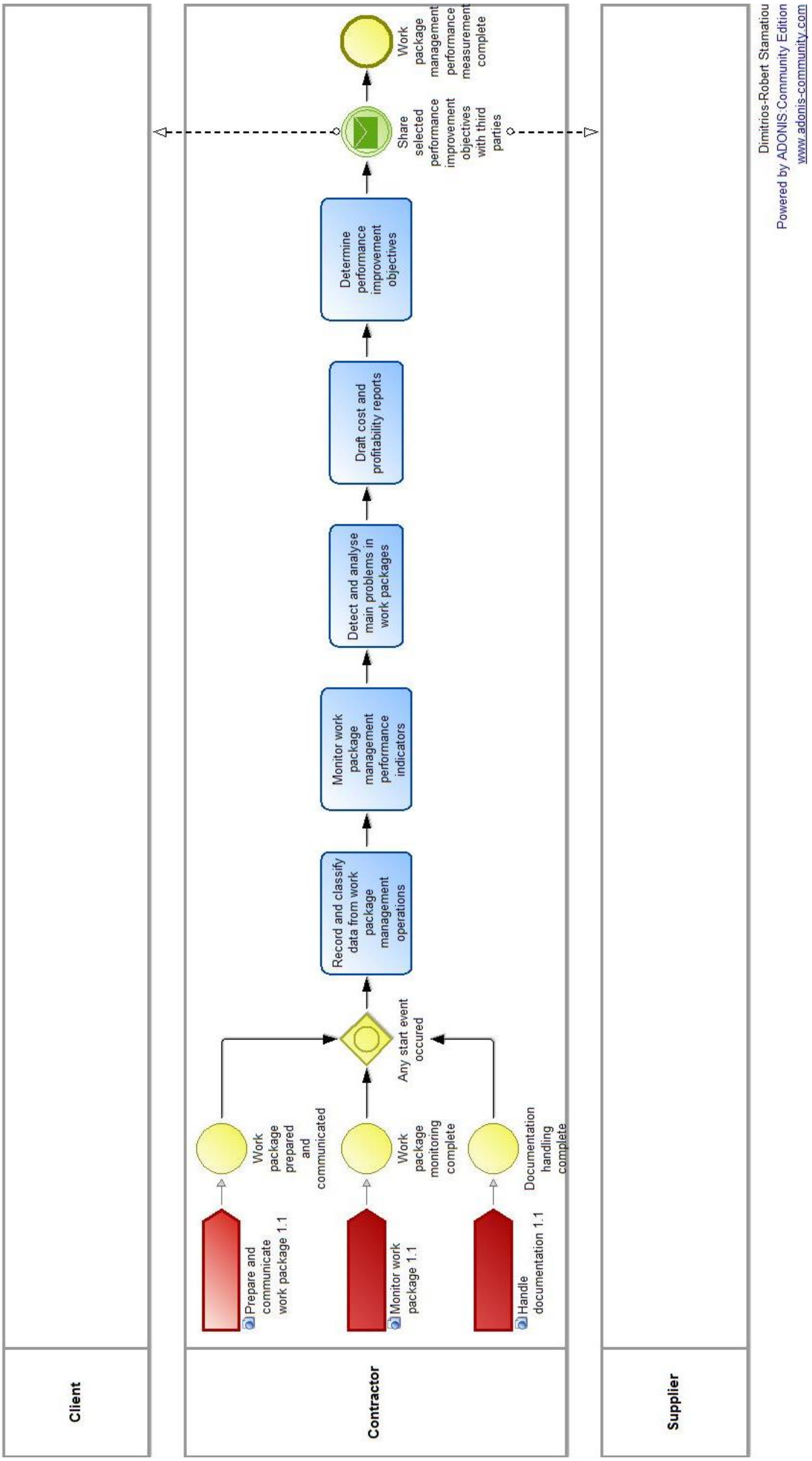

Figure 85: Work package management performance measurement

4.9. Construction flow management

4.9.1. Analysis of construction flow management

Fragmentation and specialisation of the construction industry affect both work on the construction site and upstream supply chains (Chavada, Dawood and Kassem 2012). Logistics in the construction industry, the 'internal logistic system' as it is called, is in the literature spotlight as part of the total supply chain (Sobotka 2000). The incorporation of site logistics into the whole supply chain management theory can provide even better results for the construction industry (Persson, Bengtsson and Gustad 2010). Vidalakis et al. (2011) analysed the related literature and categorised the two approaches as "facility" and "supply chain" logistics. In the first case, material flow during construction is the subject of analysis and in the second case, the interactions between suppliers and customers are analysed and ways to improve them are investigated. Persson et al. (2010) divide logistics in to logistics from raw materials to the construction site and construction site logistics. This division coincides with the one Vidalakis et al. (2011). Ebel and Clausen (2007) identify unobstructed flow of construction materials and building machinery to the construction site as a critical parameter of continuous working processes. Guffond and Leconte (2000) define logistics management as:

"(a) mobilizing the various resources required by the activities (materials, products, equipment, workforce, technology and of course associated information); (b) ensuring that the resources are being productive, in other words that they are in the right place at the right time; and finally (c) creating the conditions which enable work to be carried out properly: ensuring quality, safety and efficiency".

Construction site logistics are complex, requiring the execution of many distinct tasks, like the following listed by Brockmann (2012): mobilisation and resourcing of the logistics team; materials delivery and handling; transport and communication; managing critical safety risks; security; coordinating temporary accommodation and services; waste management and good housekeeping. Material delivery delays to the worksite result in delays in entire construction projects (Assaf and Al-Hejji 2006). Additionally, changes incurred to the project, regardless to their causes, affect the construction schedule and construction companies need to assess the flexibility of their planning practices and improve them if necessary (Beary and Abdelhamid 2005). An analysis of the relative literature is performed and then the proposed model is described.

The term logistics encompasses operations such as production planning, materials handling, and requirements planning among others. Hamzeh et al. (2007) describe logistics' purpose as efficiently moving materials, services, funds and information up and down the supply chain, considering the entire function as the back bone of supply chain management. In construction, production of the final product takes place on-site with the transfer of goods and resources to the worksite. Construction production theory considers information from owners and/or architects and resources as process inputs and construction objects as outputs (Thiengburanathum and Diekmann 2002). Ebel and Clausen (2007) recognise three categories of construction logistics: supply logistics to the construction site, site logistics and disposal logistics. These systems count for a large part of the total costs and affect the total lead time in any construction project (Persson, Bengtsson and Gustad 2010). Current practices have lead times disproportionately long to the of value-added time needed to execute each single task or a sequence of tasks that make up a process in the supply chain

(Arbulu et al. 2002). Rogers (2005) identified the following results attributed to bad logistics: unnecessary cost in the system, poor image of the construction industry, poor quality construction, increased project time, added risks to health and safety. Construction logistics require the participation of many parties, but despite the slower realisation of good logistics in the construction industry, it is up to the involved parties to integrate their work in order to obtain those benefits (Rogers 2005). Integration in construction supply chains is hard to achieve because of the huge number of available subcontractors and their locality. Subcontractors impact the nature of flows in construction supply chains and the ability of construction managers to control work flow by diverting contractors' efforts to managing contracts rather than work itself (Sacks 2016). There are reported cases of successful integration of construction supply chains, like the Japanese housing industry reported by Gann (1996), where management of the entire production system from supply chain management to factory production, sales and on-site erection proved highly beneficial to the industry.

Resources in the construction site can be categorised in two double axes according to Thiengburanathum and Diekmann (2002): renewable (e.g. labour) / non-renewable (e.g. materials) and shared (e.g. multi-skilled crews) / unshared (single-skilled crews). The lack of specified procedures for handling incoming materials and tracking systems causes many problems in the material sourcing process (Thunberg and Persson 2014). Mello et al. (2015) conclude that "*the coordination mechanisms adopted to manage the engineering and production interface need to be compatible with the coordination effort in each project situation*". Construction project schedules are heavily dependent on demand forecasts for resources (Hamzeh et al. 2007). The outcome of resource consumption and the respective production are structural units such as the spaces of a building or the sections of a road which constitute the actual production flow in construction (Sacks 2016). The integration of the logistics question into all construction site practices has gained attention since this approach prioritises advanced preparation of the construction site, and encourages all implicated parties to prepare their requirements, identify shortcomings and optimise the use of their resources (Guffond and Leconte 2000). Waste is produced by the consumption of input and can be considered as unwanted output. Poor logistics amplify the waste problem (Egan 2002).

Logistics of the construction site are very different to the logistics of a production line. The final product is immobile and all other parameters of production are highly affected by this characteristic. Sacks and Harel (2006) underline that "*the reliability of a project's short-term production plan strongly influences the resource allocations of subcontractors to projects because their perception of the risk of low productivity is directly related to the quality of the information they have concerning the project's production status*". The uncertainty related to the worksite causes a series of logistical problems to the suppliers' inventory policy, by mainly affecting inventory costs and availability of goods, and these effects stretch to the quality of service contractors receive (Vidalakis, Tookey and Sommerville 2011). Poor scheduling on the contractors' behalf leads subcontractors to adopt defensive behaviours allowing buffers of locations or time to accumulate before committing resources (Sacks 2016). Brockmann (2012) described the organisation of construction logistics as based on the "Oops!" principle, scilicet, ordering and deliveries take place when work is halted due to lack of required materials, a practice that leads to frequent delays, loss of time and additional costs caused by express deliveries. Lack of planning in advance and reactive practices can lead to insufficient ways of working and allows repetitive mistakes (Thiengburanathum and Diekmann 2002). This leads to a vicious cycle, as Sacks (2016) describes, that “*insufficient or late supply of resources in turn increases the instability of the plan*”. Lack of planning could also lead to the opposite effect; that of materials being delivered to the construction site well before they are needed. Traditional procurement methods may avoid material suspensions or shortages, but earlier materials’ entry to the worksite increases the cost of material management, the cost of repeated handling, and interest loss due to excessive buy-ins of material (Pan, Lee and Chen 2011).

Storage on-site, an area that in most cases is highly unsuitable, has to be adopted in cases of early delivery. This usually results to interruption of work, extra handling, breakage and loss, and not otherwise needed storage capacity (Brockmann 2012). Construction site space constraints are one type of constraint. Resources and their nature are another. Resources are re-assignable to many different tasks and they must often be shared (Slaughter 1999). Bertelsen and Sacks (2007) state that a portfolio of construction projects, unlike neighbouring factories that are autonomous regarding their resources, is comprised of projects co-dependent on the same subcontractors and their labour in any given economic region. In order to maintain continuous occupation of their work crews, subcontractors balance their workload across regional projects, creating a flow of labour between the operations of different projects (Sacks 2016). Xue et al. (2007) identify tight schedules and unrealistic lead-time requirements for material and equipment as problems that do not allow for seamless construction logistics. Thomas et al. (2005) stress out the importance of effective management of materials on-site, especially when confined space poses increasing difficulties. Correct storage of the materials on construction site is very important to prevent the material from being contaminated or damaged due to the rough conditions on site (Ebel and Clausen 2007), but this is usually not the case. In the majority of projects on-site storage causes high rates of waste. Spillane et al. (2011) underline that lack of adequate storage space, lack of adequate room for the effective handling of materials, damage occurring due to poor material management and lack of adequate room to account for materials all relate to material waste on-site.

Brockmann (2012) identified the following nine symptoms of bad materials management on-site: much internal transport, storage on the building site, great losses, much pilfering, lack of materials, errors in deliveries, plenty returned materials, breakage, damages upon work already made and attributed them all to the following causes: insufficient planning of the work and the deliveries, quantity discounts, errors in drawings and specifications and other human errors. Further causes for bad materials management are the following identified by Spillane et al. (2011): contractors’ material spatial requirements exceed available space, difficulty of coordinating the storage of materials in line with the programme, location of the site entrance incommodes delivery of materials, difficulty of storing materials on-site due to the lack of space, and difficulty of coordinating the storage requirements of various subcontractors.

A solution to these problems could be seen in the advent of on-site or off-site consolidation/logistics centres. Bertelsen and Nielsen (1997) found that delivering building materials on conditions laid down by the construction site could provide a substantial increase in productivity. Hamzeh et al. (2007) support that the need for logistics centres is expected to increase in the construction industry as companies look for ways to reduce lead time, delivery uncertainty and logistics costs. Meidute (2005) performed an extensive survey of available literature and concluded to the following definition for logistics centres: "*A logistics centre is a focal point for material flow streams in a logistics chain. It thereby provides access to different shipment modes, performs broad logistic functions, serves a wide range of users, presents information technology solutions, and offers value added services*". Logistics centres are versatile by their nature. They can offer a multitude of functions such as the following highlighted by Hamzeh et al. (2007): storage, transport, distribution, assembly, direct shipment, shipment with milk runs, cargo consolidation, sorting, break-bulk, distribution network management/vehicle routing, delivery, package tracking and e-commerce services. There is no point in keeping all products in logistics centres though since demand for certain products can be very low, their cost very high or their depreciation quite fast. Products that are standardised and used frequently (e.g. plasterboards, wood products and insulation) can be kept in stock at a logistics centre and benefit from the service (Persson, Bengtsson and Gustad 2010). Brockmann (2012) recommends the adoption of logistics centres as a prime solution for logistical problems because of their ability to concentrate the flow of materials and allow for specialist handling by a logistics team. A setback to the adoption of logistics centres is the high cost of their acquisition and repletion. In this spirit Vidalakis et al. (2011) support that maintaining high-level inventories seem prohibitive to contractors.

Logistics of work crews is critical on the construction site. Work crews perform all operations on site and the completion of a project involves a variety of skilled crews that move from work site to work site. This makes regulation and coordination essential everywhere (Guffond and Leconte 2000). Scheduling the precise location of a work crew, particularly if there are multiple crews, and leaving no room for dispute about where work crews should be physically located and, especially, where they shouldn't, minimises management problems (Kenley 2004). Sacks (2016) describes work crews as flowing not only from location to location within a project, but also from location to location across projects and operations as extending across projects, reflecting interdependence between projects. Especially when handling a portfolio of projects, every construction site is considered a project and many projects are performed simultaneously (Persson, Bengtsson and Gustad 2010). It is common for skilled craftsmen and their crews to spend a lot of time on site without using their skills; Rogers (2005) estimates this time spent as over 50% of the total productive time and identified non-skilled tasks that consume time (such as unloading lorries and moving products around site). Despite the time work crews allocate to logistics activities, they tend to be ineffective when performing them. Rogers (2005) attributes this fact to the very low level of formal training in logistics in comparison to other markets, despite the large number of tasks that fall within the logistics umbrella. Furthermore, Ebel and Clausen (2007) identified that management overhead in construction is quite small compared to other industries, leading to *"most actions on construction sites being "managed" by workers who prefer a pragmatic solution"*. Most tasks on the worksite are performed by subcontractors and their crews. Ebel and Clausen (2007) state that: "*Each trade has a specific organisation of supply which is mostly coordinated by the trade itself and since all construction companies use common resources on the construction site coordinating is indispensable*". Taking into consideration the distribution of control over worksite flows across owners, general contractors and subcontracting companies, Sacks (2016) deems collaboration as essential. But there is a problem with collaboration in the construction site. There is a conflict of interest between work crews and general-contractors regarding changes in the modus operandi. As Rogers (2005) highlights, "*those who may be required to do things differently* *do not necessarily benefit*", hence there is no real incentive to tackle existing inefficiencies because it is not always clear who benefits from the proposed changes. Just as in manufacturing and retail sectors, it may be useful to utilise designated work crews to handle construction site logistics. Brockmann (2012) proposes that the use of dedicated logistics teams in construction sites is dependent on the size of the project.

Work crews are one of the parameters of the problem in construction logistics. Another is the space available to crews to perform their tasks. Space is a resource used by one or more workstations and is a main point of differentiation between the construction and the manufacturing process (Thiengburanathum and Diekmann 2002). Dawood et al. (2005) identify space as one of the main resources and constraints that affect the delivery of construction projects. Multiple trades that may require different workspaces as working areas for labour or working space areas for material storage, people, equipment and support infrastructures have to share the same confined space effectively (Chavada et al. 2012). Most construction projects take place in urban and suburban areas where space is highly limited. The construction site evolves and changes as time goes by and this makes proactively planning and managing workspaces a demanding task (Chavada et al. 2012). A proposed solution to this problem is the prefabrication of construction parts. Goulding et al. (2014) identified the following terms used in the construction literature to refer to prefabrication: manufactured construction, Offsite Production (OSP), offsite construction, offsite manufacturing, industrialised building systems, and modern methods of construction. Prefabrication is not a new fad in construction. Thirty years back Kendall and Sewada ((1987), as seen in Gann (1996)) identified two types of prefabricated components: "*those that were produced without prior knowledge of the design or type of building, and those that were produced for a specific building only after the design had been completed*"[6]. Prefabrication limits the extent of work on site depending on the degree and level of customisation required by the clients (Gann 1996). This leads to easier programming of the space use on the construction site. In his report Rogers (2005) endorses prefabrication as a method to reduce on site work and to assist work planning, despite the relatively low level of acceptance it has in the construction market. This low acceptance is attributed to inaccurate public assumptions regarding prefabrication in construction (Taylor 2009), but Goulding et al. (2014) propose that prefabrication can deliver a tighter building envelope. Furthermore, the gaining in popularity focus on sustainability is an opportunity for offsite construction to present itself in a very positive new light (Goulding et al. 2014).

In any case, with or without the use of prefabricated parts, job queuing in the construction site poses an intractable problem. Advance planning and design of projects is generally inadequate, as are lead times (Rogers 2005). The lack of forward planning means that the work site could either be overflowed or short on materials. Hamzeh et al. (2007) underline that material shortages are expensive in construction resulting in lost production, lost resources, execution of out-of-sequence activities, delay in subsequent activities and other problems. The particularity of construction is that all materials required for work to take place have to be hauled to the construction site. Inadequate job queuing means that many transporters may travel bellow full capacity increasing transportation costs, or upon arriving at construction sites they have to wait to gain access or be unloaded because of poor delivery scheduling on the site manager's behalf (Rogers 2005). Besides materials, another

[6] One can easily make the connection to the make-to-stock and make-to-order production strategies in manufacturing.

phenomenon linked to poor job queuing is subcontractors arriving on site for work unexpectedly and without preceding work being complete. This may occur due to poor communication with subcontractors during the planning phase or by subcontractors not being informed on delays that affect their programme. Delays, in general, affect many aspects of the worksite. Hamzeh et al. (2007) underline that, whenever durations vary from planned schedules, complexity is added to material management due to changes in delivery dates. Construction usually uses buffers to conceal variations in a system (Ballard and Howell 1998), this is why it is important for job queuing to stay on schedule. Al-Sudairi and Diekmann, (1999) characterise zero buffer size causes as a fragile and unreliable condition of the construction process. Zero buffer in construction is related to Just-In-Time practices (Thiengburanathum and Diekmann 2002). Additionally, when a certain output is planned by the contractor, it should take into consideration the capacity of its own resources and that of regional subcontractor resources (Sacks 2016).

Lean construction is considered by some academics and practitioners as the answer to most of the problems faced during planning and executing tasks on the work site. It is based on the lean production principles, the western take on Ohno’s Toyota Production System. According to Sacks et al. (2017), the application of lean techniques requires the existence of conditions such as near equal Takt times across all trades, stable production rates for each trade crew, small batch sizes, minimised waiting/time buffers between operations, minimised non-value-adding time within operations, satisfactory quality to avoid delays for rework, minimised number of operations, just-in-time delivery at the junctions where subsidiary process flows meet higher-order flows, and just-in-time delivery of raw materials. There are many benefits to be gained by adopting lean practices. According to Howell and Ballard (1998) lean construction maximises value and minimises waste through achieving the goals of three dimensions of perfection: a uniquely custom product, delivered instantly, with nothing in stores. Lean thinking brings into attention the concept of value generation through the entire project instead of the management of each activity (Beary and Abdelhamid 2005). Activity-based scheduling and location-based scheduling are methodologies for scheduling work that still need to be clarified in the lean environment (Kenley 2004). Al-Sudairi (2007) proposed that lean principles, besides being effective in complicated processes, are also effective in simple processes. Gao and Low (2015) describe fourteen principles of lean production that could present opportunities for improvement in construction, including standardisation, relationships with other parties and long-term philosophy. Trust and collaboration between contractors and subcontractors have been identified by Miller et al. (2002) as a prerequisite of lean construction adoption. Gao and Low (2014) propose that partnerships based on Toyota principles would bring a new angle to lean practices, including respect, reduced supplier base, direct involvement and long-term relationships. Unfortunately, construction suffers from a high percentage of damaged products and waste which leads to the need for a lot of secondary work on site (Rogers 2005). The adoption of lean practices is inhibited by the lack of inventory management systems on construction sites (Ebel and Clausen 2007). Green (1999) performed a critical review of lean practices on human resources and labour autonomy on site and identified that such issues remain unaddressed. Winch (2003) also criticised lean construction and found little relevance of contemporary literature besides mass housing production due to the complexity of other construction projects.

The advancement of information technology, along with increased market competition, support the adoption of supply chain management strategies to seek competitive advantage (Hamzeh et al. 2007). Construction site logistics, in particular, can benefit from the development of software and information technology. The ever-growing capabilities of software, hardware and networking have allowed the development of BIM (Building Information Modelling) software packages. The concept of BIM has existed since the 1970's but recent developments in IT have allowed it to mature (Kiviniemi 2011). MacLeamy (2012) characterise BIM as "*the first truly global digital construction technology*". The use of BIM software has increased in the construction industry because it enhances value generation by improving requirements management, transparency and communication (Dave et al. 2008). Although the majority of BIM tools is mainly built for project design (Deshpande and Whitman 2014), the tool can be also used in order to assist the management of the project supply chain (Pala et al. 2013, Papadonikolaki, Vrijhoef and Wamelink 2015). There are modules to the software that allow access to data of a specific project to parties outside the contractor. BIM can be considered as a collaborative vehicle for all project parties to share their knowledge, resources, and information and enhances collaboration in three dimensions according to Lu et al. (2013), these of collaboration team characteristics, collaborative environment, and collaborative process. Assistance for collaboration has to be provided to construction companies due to their lack of trust. In this direction, Redmond et al. (2013) propose a framework for exchanging partial sets of BIM information through cloud services. This has multiple positive effects for offsite construction, including faster delivery, improved economic indicators, along with improved sustainability factors and enhanced safety measures (Nawari 2012). BIM can be combined with simulation in order to improve logistics management when planning and examining changes and their potential effects (Sobotka 2000) and to proactively simulate conflicts, bottlenecks, and use of the workspace (Chavada et al. 2012). Despite the obvious benefits stemming from collaboration through BIM integration, there are legal, business, human, and technical problems that need to be resolved before construction companies can reap them (Kiviniemi 2011).

4.9.2. Construction flow management process model

The "Construction Flow Management" function is comprised of seven processes; three strategic and four operational (**Figure 86**). The strategic processes can be executed in parallel or sequentially according to the needs of a specific project or the entire project portfolio, and are as follows: "Determine level of flexibility for construction process", "Determine construction strategy limits" and "Determine construction constraints and requirements". Operational processes are executed often, even at weekly or daily basis, and are, based on Leblanc et al. (2013), as follows: "Determine long term plan of work", "Plan work and resources", "Work execution" and "Construction flow management performance measurement". The first three operational processes are executed sequentially, but the fourth one can be executed either in sequence of all or in parallel to each of the other operational processes.

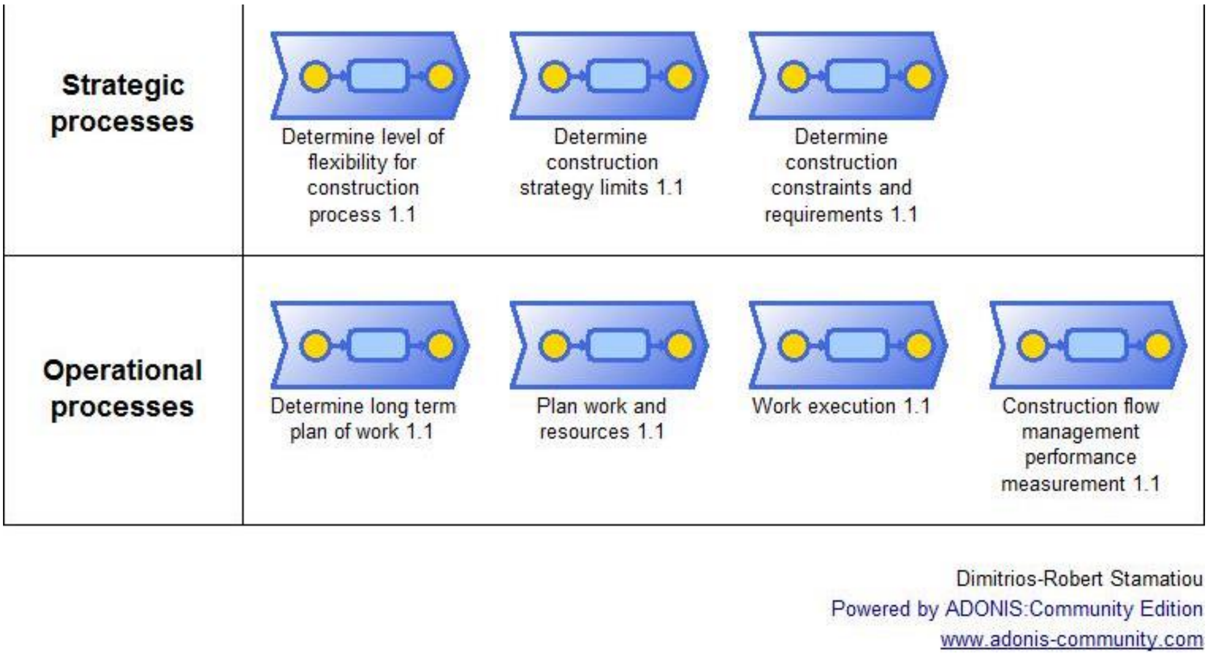

Figure 86: Construction flow management function tree

4.9.2.1. Strategic processes

The first strategic process is “Determine level of flexibility for construction process” (**Figure 87**). Flexibility is important in day-to-day construction site logistics because many unforeseen events may occur and set work back or even bring it to a halt. The contractor, specifically the project manager, has to ‘Determine level of flexibility in tasks’. This means proactively planning changes that can be made to the schedule and the related logistics based on the clients’ time tolerance, supplier batch sizes and construction cycle times. This task usually produces a few scenarios with different flexibility levels that lead to the next task; to ‘Determine required time for task completion’ in each scenario. The most important limitations in each scenario are cost and time. The next task, ‘Evaluate adequacy of current capacity’, aims at identifying any staff or equipment shortages that might jeopardise the applicability of the selected scenario. This may lead to further development of capacity if it is deemed necessary. This leads to a very important task, the ‘Determine make or subcontract decision’ task. Through this task the contractor selects project specifics that will be handled internally or contracted to subcontractors for execution. Finally, the ‘Evaluate suppliers level of flexibility’ task aims at analysing the ability of suppliers to respond to planned or unplanned changes of the project schedule whilst keeping an acceptable level of service. This can be achieved by retrieving previous data from suppliers that took part in relatable projects, performing audits or by requesting a specific level of supplier flexibility during contract negotiations.

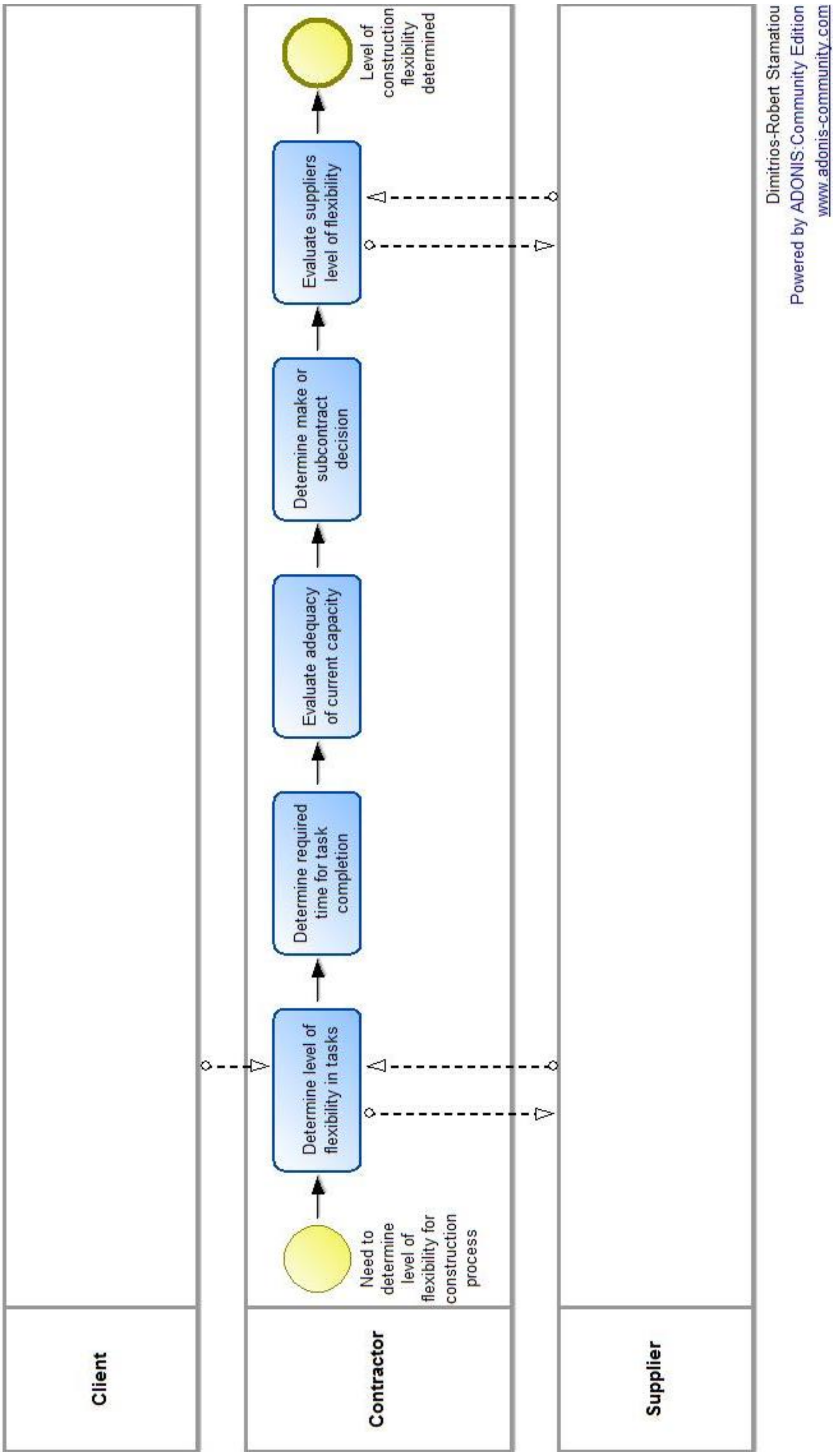

Figure 87: Determine level of flexibility for construction process

The second strategic process is “Determine construction strategy limits” (**Figure 88**). The first task, ‘Review customer service goals’, aims at identifying the customers’ needs and determining the appropriate level of responsiveness in order to perform accordingly. Levels of service in construction relate to what a service provider is required to provide as part of the agreement and the standard that those services must achieve. This is usually set through the contract, after it has been debated and agreed upon by both sides. High levels of customer service come at a high monetary cost. The levels of service agreed with the client affect the agreements with the suppliers, especially overseeing activities and decisions for reworks. The next task, ‘Recognise differentiation points between projects’ aims at identifying the characteristics that differentiate each project regarding the complexity and constraints of the worksite logistics. It is especially important in case the contractor operates a storage facility for local projects. The results of this task highly affect the next task, that of ‘Determine inventory points’. Inventory points pose a hurdle for worksite management, especially in cases of confined space. For example, in an urban project space may be a strong constraint factor leading to the decision of creating a consolidation point at another site and then transporting the exact amounts of goods required at a daily basis. Finally, the task ‘Determine the applicability of push/pull tactics’ relates to the positioning of decoupling points in the supply chain (Goldsby and García-Dastugue 2003). In construction, the final product is immobile which means that the concepts of push and pull need to be adapted. In their seminal works on lean construction, Ballard and Howell (1995), Howell and Ballard (1998) and Koskela (1999) describe push practices in construction as traditional schedule based distribution and consumption of resources and release of work into inventories of assignments, whereas pull practices establish a cap for work-in-progress allowing for control over production that includes references to successor readiness. Simply stated, pull assures flow in contrast to the scheduled push of resources. Pull has many advantages compared to push, including reworks. As Sacks (2016) states “*rework to correct defects, to revise work performed prematurely due to ‘push’ control, or as a result of late design changes is an additional, unplanned but common source of re-entrant flow patterns in construction*”.

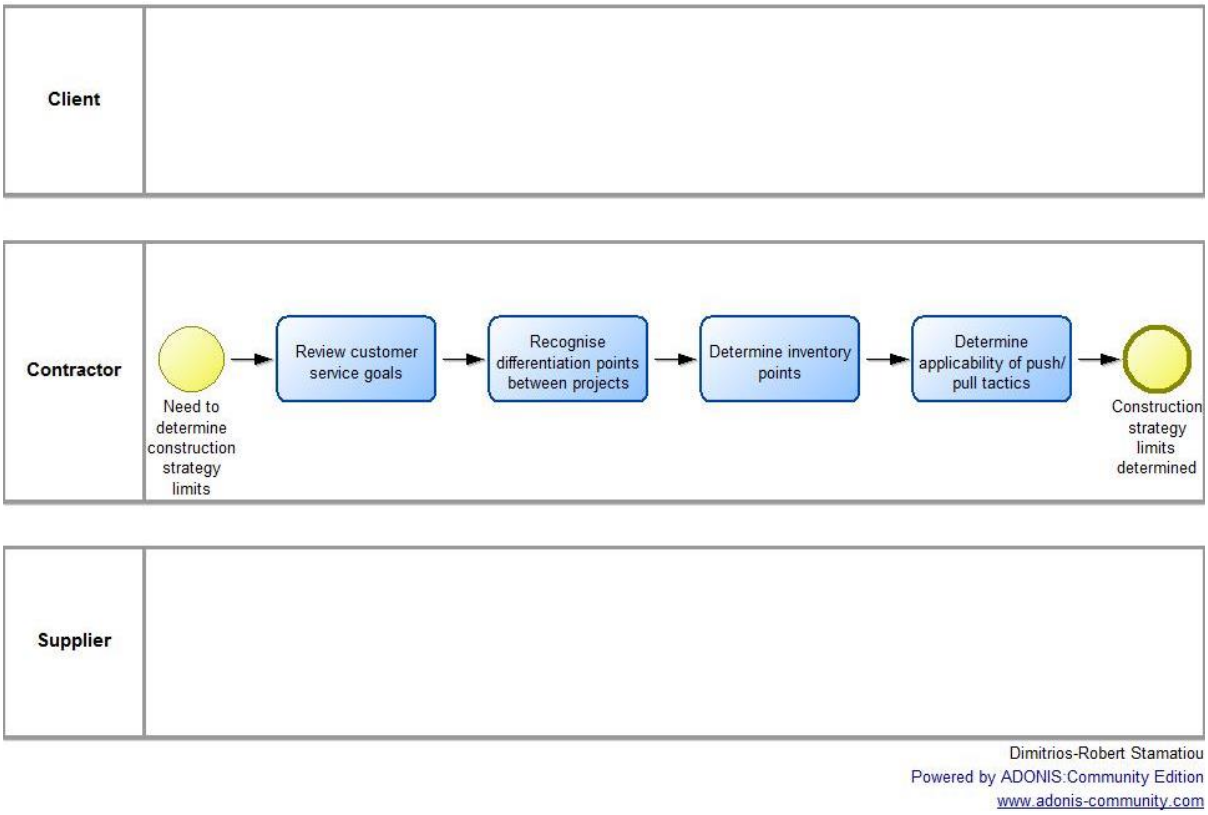

Figure 88: Determine construction strategy limits

The third strategic process is “Determine construction constraints and requirements” (**Figure 89**) and aims at identifying requirements or constraints at the construction site imposed by the nature of the site itself or by other supply chain actors. The first task is to ‘Identify bottlenecks in tasks’. A bottleneck is part of a task that has the largest impact on the whole task due to limited capacity. This can be production, construction or otherwise capacity. In construction, bottlenecks can be created by limited capacity of equipment or subcontractors and are almost certainly present in tasks that cannot be executed alongside others (e.g. cement curing). These bottlenecks provide constraints for consideration when applying lean practices. Next, the ‘Study resource adequacy for current and future demand’ task aims at providing a plan for the management of demand levels. This may include decisions on increasing/decreasing staff, additional subcontracting and equipment provision or sale. This study should be updated periodically in order to monitor changes in demand and adapt the plan accordingly. In collaboration with other supply chain actors, the contractor should execute the task ‘Develop communication mechanism for participants’ synchronisation’ whose result is known and accessible by all parties involved in construction logistics. Information may be selected depending on the party it is available to. This provides a sense of cooperation within a safe environment. Information may regard reimbursements due from the clients’ side for work scheduled on the suppliers’ side. Next, the contractor must 'Determine quality criteria’ for the suppliers, as those are described in the contract with the client, evaluate how these affect site logistics and communicate them to the suppliers. The contractor must coordinate many suppliers and their good cooperation on the work site is critical for project success. This cooperation should stay within site boundaries. The contractor must make sure to ‘Examine waste disposition requirements’, communicate them and make sure that involved parties cooperate smoothly. Finally, before commencing a project, the contractor has to 'Check for health and safety constraints on site logistics' and study how these constraints affect site operations and project execution.

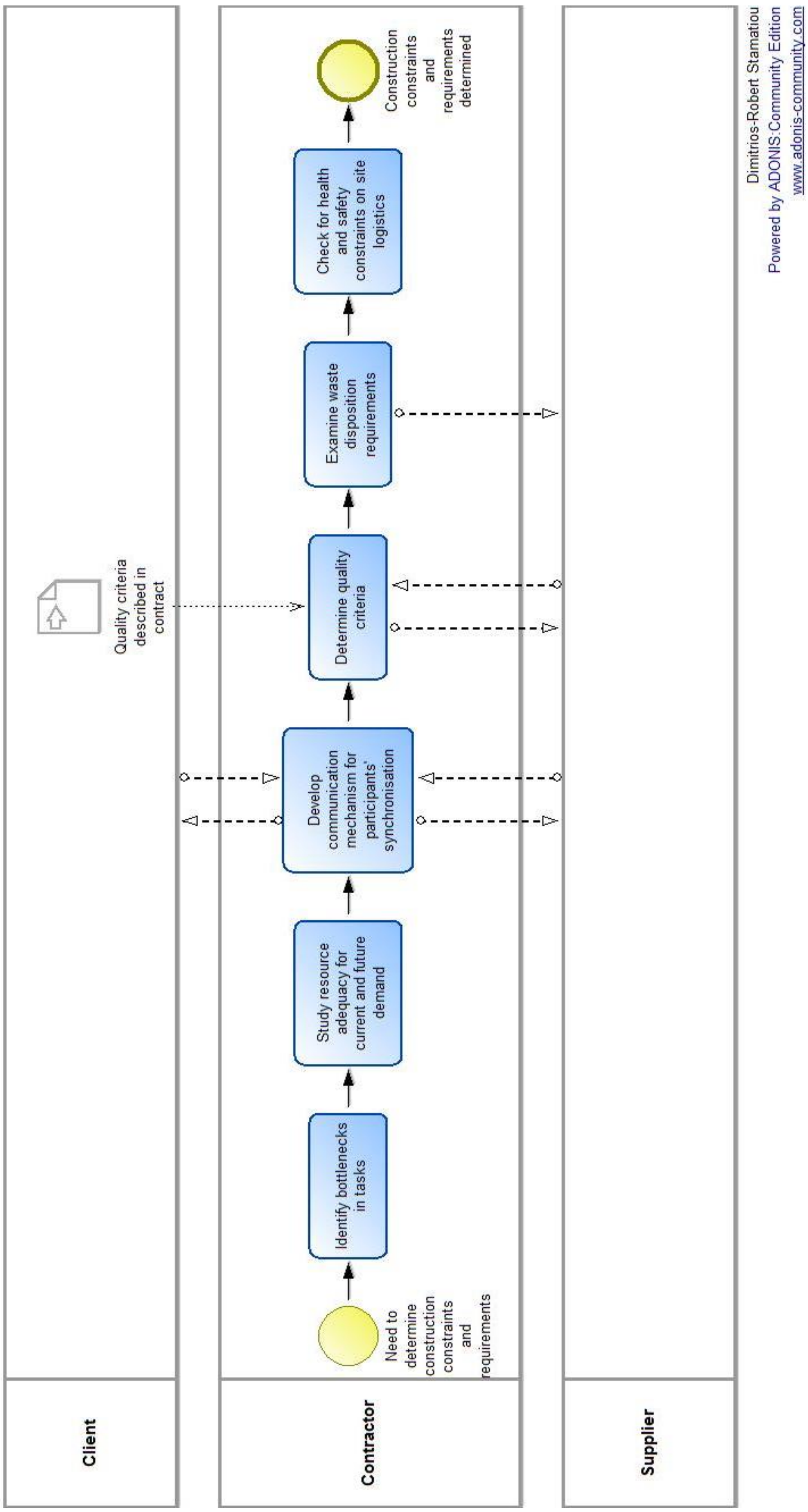

Figure 89: Determine construction constraints and requirements

4.9.2.2. Operational processes

The first operational process, “Determine long term plan of work” (**Figure 90**), is initiated by a need to create a long-term plan for construction work logistics. The first task is to ‘Distribute total construction schedule to Construction Department’. This includes long-term schedules for the entire portfolio of existing and new projects. Next, the department staff has to ‘Review total construction schedule’ and identify projects that are behind schedule, prioritise projects and highlight upcoming critical tasks that need a focus of resources. If the portfolio becomes too big, the staff in the Construction Department will not suffice and control over projects may be lost. This creates the need to ‘Evaluate Construction Department capacity’. Once the evaluation has taken place, the task ‘Analyse tasks of each project’ is executed in order to identify the input, resources and output of each task aiming to assist the short term planning that follows. This will identify the construction volume and timeline of following activities. Next, the task ‘Study parameters that affect total production schedule’ aims at identifying new parameters of the ever-changing work sites that may affect scheduling of work and resources. Interviews identified health and safety, bureaucracy, finance and environmental characteristics as such parameters. Furthermore, the ‘Check construction constraints’ task that follows aims at identifying similar parameters that stem from the project environment and not from the work conducted. Additionally, the identified constraints should be communicated to the suppliers through the ‘Communicate with suppliers’ task. Contractors in some cases provide their suppliers with target dates and interface schedules (Brown et al. 2001). The suppliers can also provide their own insights. This leads to the final task, ‘Specify possible courses of action in cases of unforeseen events’, proposed by Thiengburanathum and Diekmann (2002), that aims to provide contingency plans for site logistics in case things go wrong. The results of this task depend on how tolerant each client is to changes, according to the conducted interviews. Interviews revealed that this entire process is executed only once during a project (upon project initiation) and its result is called a ‘baseline plan’ that can take minor modifications during the project execution. The baseline plan presents the original intentions of a contractor and only under extreme circumstances can it be ‘re-baselined’.

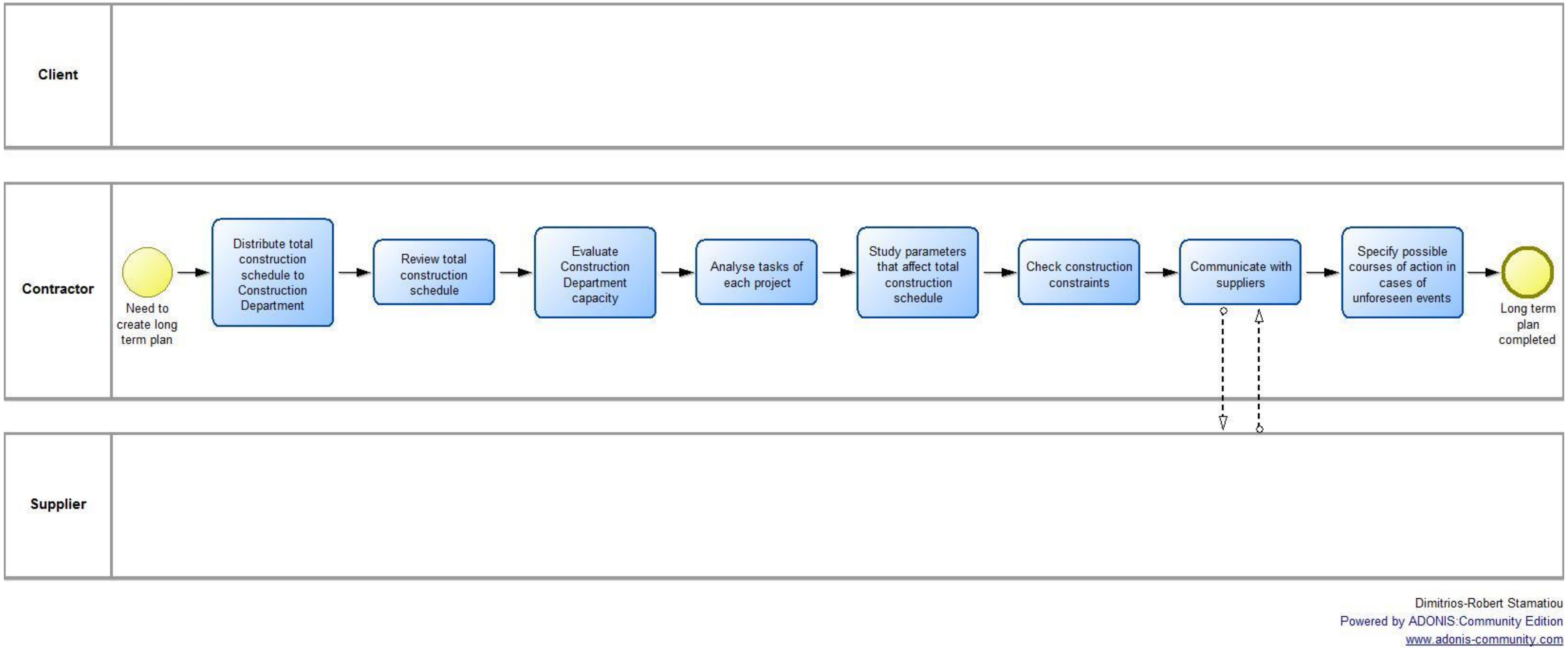

Figure 90: Determine long term plan of work

The second operational process is "Plan work and resources" (**Figure 91**) and relates to short term, even day-to-day planning on the worksite. The first task is to 'Use line-of-balance technique to plan work'. This technique is advocated by lean construction enthusiasts, such as Kenley (2004) and Sacks (2016) among others, as the planning method with the least waste and the best coordination of the work site. Line-of-balance is a time based graphic technique that places repetitive tasks in a sequence of execution which allows continuous and undisrupted workflow. Despite its benefits, interviews showed that it is mainly used by SME contractors (depending on the scale of a project) and less often by large contractors. Next, the contractor must 'Determine subcontractor requirements' (Guffond and Leconte 2000). This task includes an information exchange between the two sides regarding time, resources and prerequisites for work planning that aims at collaborative scheduling and prevention of on-site conflicts. In this spirit of collaboration, it is important to execute the task 'Provide access to BIM or other collaborative software', especially with key-suppliers and the client of each project. BIM has multiple benefits to offer and it supports supply chain practices effectively. Interviews showed that BIM is used by large contractors, but not in order to directly plan resources at a daily basis, whereas it is not used by SME contractors and file sharing tools are preferred along with the placement of cameras on the work site. Next, in collaboration with suppliers, the contractor's staff should 'Determine raw materials, ready, and semi-processed products/materials and their delivery times to construction site'. This includes planning the amounts of delivered products according to site needs and restrictions as well as the time, method and designated areas of delivery. In the planning of the operations all supplies must be described in detail and their assemblies are named 'units' (Bertelsen and Nielsen 1997). This has to take constraints such as single access points, limited storage space and personnel for unloading trucks into consideration (Rogers 2005). Furthermore, another problem that has to be taken into consideration is the fact that construction trucks move at a non-optimal loads (Persson, Bengtsson and Gustad 2010) for large intervals (Rogers 2005) and carry low value and high volume products creating higher transportation costs (Vidalakis, Tookey and Sommerville 2011). The benefit of communicating delivery plans to both suppliers and construction site workers is that incoming deliveries are expected, allocation areas are cleared and ready, and verification personnel is available on-site to receive materials (Thunberg and Persson 2014). Next, the contractor has to 'Solve potential material shortage problems' that may include shortages due to supplier defaults, supplier production disruptions or other risks that may have been realised. Interviews showed that time is a big factor in this task and that suppliers of SME contractors, that have built trusting relationships with their contractors, may resolve such problems themselves instead of waiting for the contractor to approve a solution. Usually, solutions to such problems are costly either because they produce sudden peaks in demand for the suppliers or because new suppliers have to be contracted at short notice. Some tasks may require additional staff, so the 'Check for staff shortages' task aims at preventing such problems. A common solution for this problem is employing seasonal staff. Next, the 'Plan for waste removal' task aims at tackling the most prolific problem causes on work sites (Ebel and Clausen 2007, Ravetz 2008). Waste is abundant in almost every operation on the work site and its management is riddled by practical and statutory limitations. Interviews showed that for large projects an environmental plan is submitted with the tender and that in all projects a certified company is used for waste removal and recycling. Waste removal causes, in many cases, damage to work completed, disturbance of the worksite and unforeseen costs. Finally, the 'Plan required rework' task is important because of the effect reworks have on the construction schedule (Sacks 2016). Reworks may even create delays in cases of deficient planning. Interviews with SME contractors showed that reworks related to natural phenomena and material failures are resolved when they occur so they do not interfere with other work that is pending and dependent on specific work to be finished.

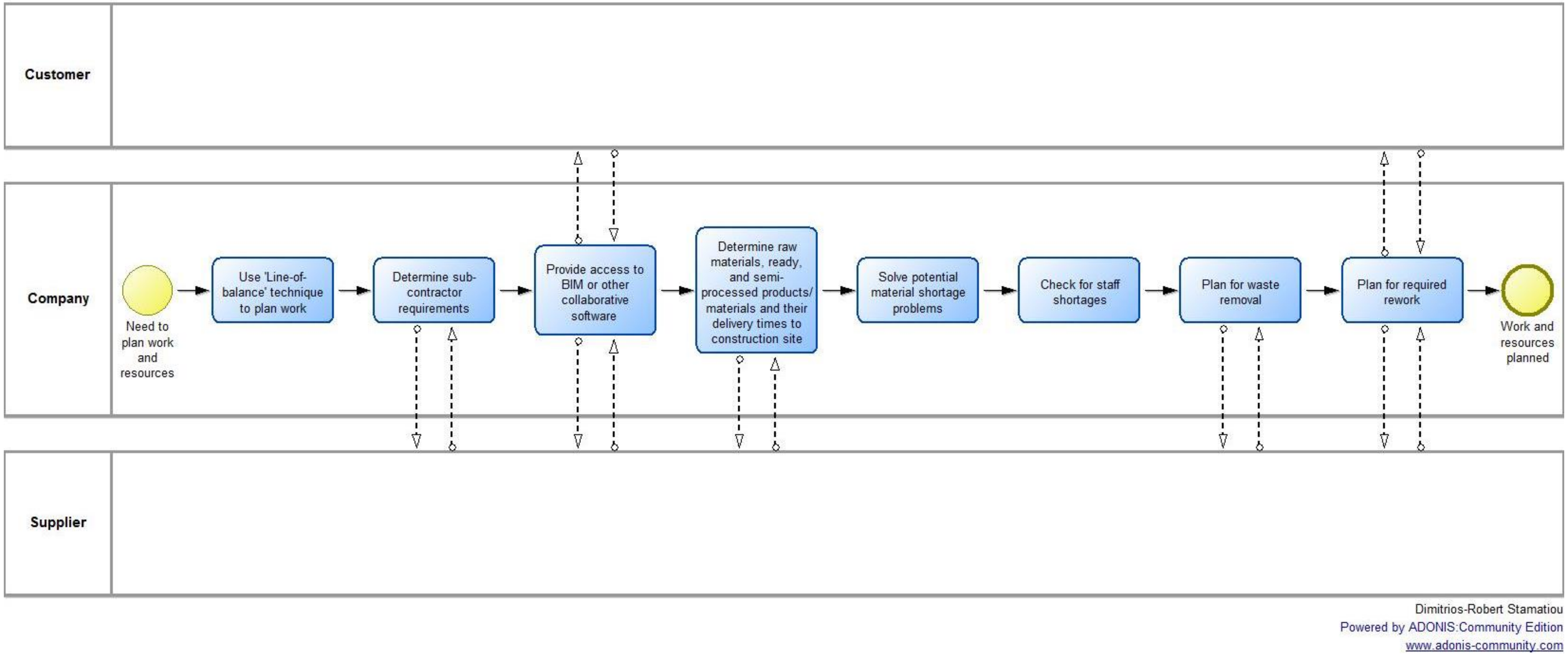

Figure 91: Plan work and resources

The third operational process is “Work execution” (**Figure 92**) and relates to the logistics during daily work. The first task is ‘Manage inventories and flow of raw materials, subcomponents and ready products’. This task relates to the monitoring of inventories onsite and offsite (in case the contractor uses a storage point), the flow of products and workers on the worksite, placement of orders and reception of deliveries to the worksite. Brockmann (2012) related the incoming stream of materials with traffic, unloading, storage and delivery, and the outgoing stream of materials is with traffic, loading of waste and discharge, while people come and leave the worksite simultaneously. SME contractors highlighted in the interviews that the size and value of the inventoried products plays a big role in the decision of onsite or offsite storage. The project manager must ‘Perform daily checks to ensure timelines are kept’ in order to identify changes to the schedule that may affect site logistics. In the case that work is to be conducted by the contractor’s staff, the task ‘Conduct work’ is executed. In the case that work is to be conducted by a subcontractor, the task ‘Control workflow’ is executed. In both cases, the quantity surveyor will use the Bill-of-Quantities to monitor the consumption of materials and provide the input for new orders. Both tasks are followed by the task ‘Manage construction site waste removal’. This task requires man-hours that do not relate to the work-crew skills, movement on the worksite and a subcontractor that will undertake the transportation and disposal of the waste. Interviews with large contractors revealed that the client’s engineer is responsible for overseeing this task. Next, the ‘Inspect work conducted and record reworks’ task is executed and aims at identifying flaws, quality shortcomings adding required reworks to the schedule and certifying that there are no deviations from the project description. Reworks will require additional time, man-hours and materials that will sum up to additional costs for the contractor and may affect the project schedule. Interviews with large contractors showed that the client’s engineer is also involved in this task. Finally, in the case of major milestones or at handoff points, large contractors execute the ‘Certify for handover’ task according to the interviews.

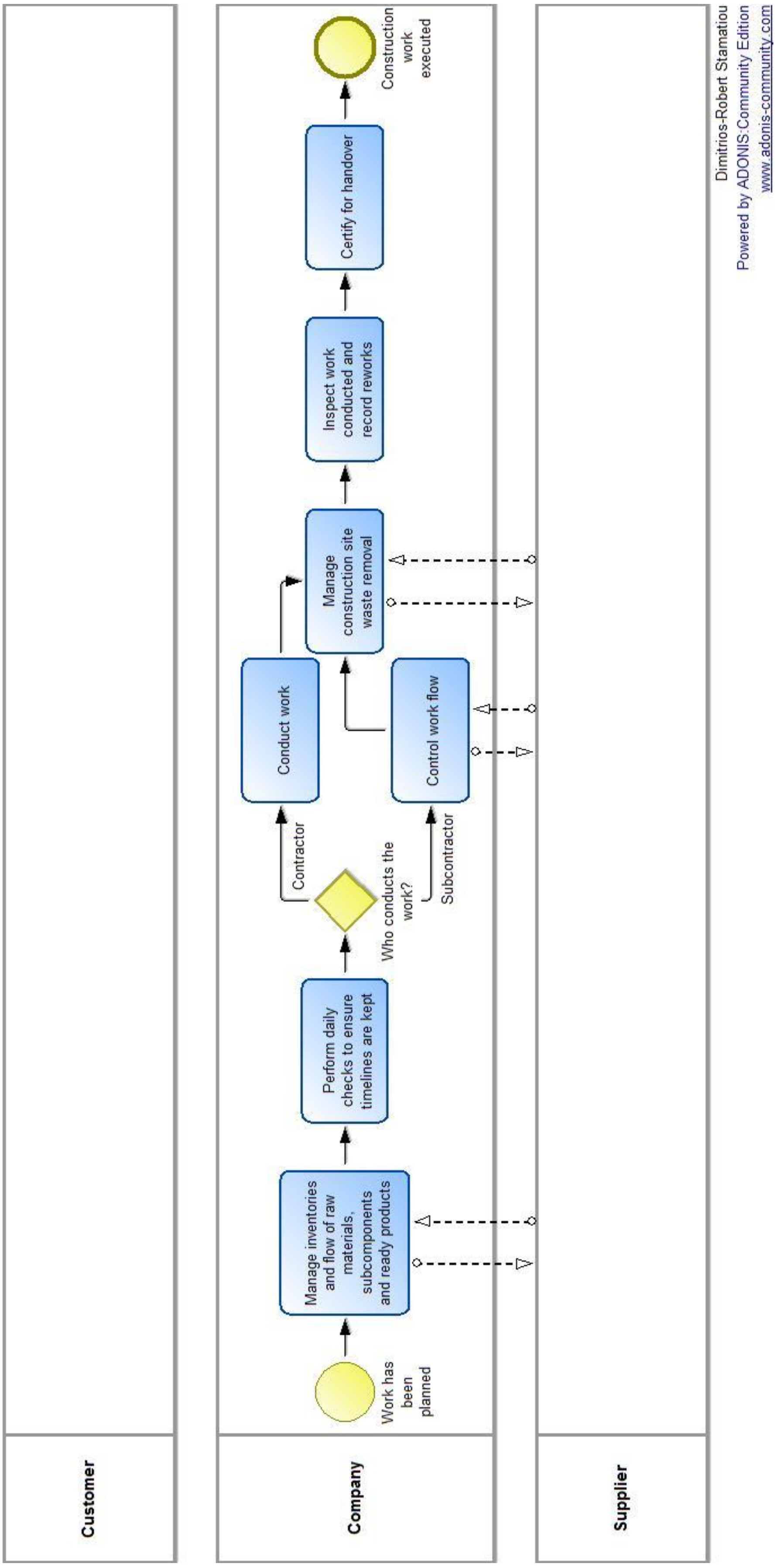

Figure 92: Work execution

The last operational process is “Construction flow management performance measurement” (**Figure 93**). It can be executed for each previous process independently or for all at once. First, the task ‘Record and classify data from construction site operations’ aims at monitoring site activities. The data that is collected can be used in order to identify operations that have been underperforming and operations that have been executed better than anticipated. Data can cover all aspects of the operations, from financial to highly technical specifics. Sacks et al. (2017) insist that the following three aspects of construction flow should be measured: flow of trade crews from location to location and between projects, flow of locations through the production process, and flow of projects viewed as units. The data collected provide input to the next task, ‘Monitor construction flow management performance indicators’, which is executed in order to compare actual performance to the targets set at a strategic level. The ‘Detect main problems in operations and quality’ task aims at identifying problems that set planning off tracks, their causes and their impact on quality. There are many tools that can be used to support such a task, such as the fishbone diagram. Next, based on the recorded financial indicators, the task ‘Compile cost analysis and profitability reports’ is executed. These reports may be required by the client, investors or financial institutions involved in the project. Finally, the task ‘Determine performance improvement objectives’ aims at using the acquired knowledge for improving performance in future projects. These objectives can be shared with other key parties of the supply chain.

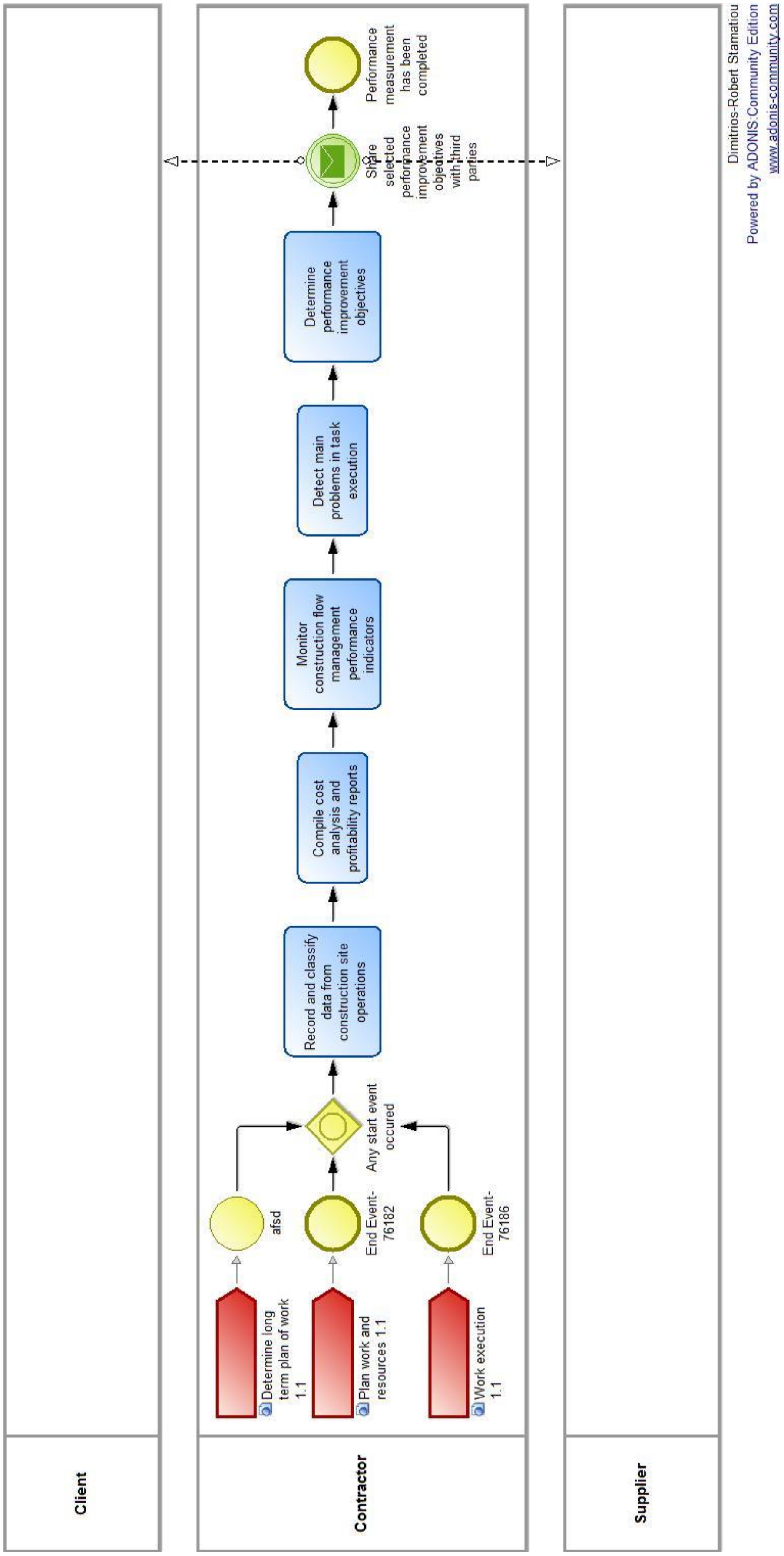

Figure 93: Construction flow management performance measurement

4.10. Claims management

4.10.1. Analysis of claims management

The construction industry is project based and characterised by complex activities, tight schedules and a tuple of actors. This is an environment where risks are abundant. It is common practice for every company to attempt to mitigate as many risks as possible. Furthermore, the industry faces new types of risks that stem from the fact that projects are becoming more and more complex due to new standards, advanced technologies, and owner-desired additions and changes (Abdul-Malak et al. 2002). These factors have an extremely strong reflection upon projects' supply chains. Relationships between actors of construction supply chains are mainly determined and guided by contracts. Contracts describe the obligations of each party, the reimbursement method and risk allocation. These contracts have clauses that provide for specific events, but due to different limitations they cannot be exhaustive. Once risks become a reality, they give rise to project cost escalation and time overruns, which can lead to claims. Claims can divert considerable resources in form of both finances and staff time from on-going projects (Sibanyama, Muya and Kaliba 2012). The larger and more complex the project, the greater the likelihood of several major claims (Revay 1993). Claims are, thus, inevitable. Due to conflicts and differences over claims, the construction industry is plagued by an adversarial atmosphere between clients and contractors (Harmon 2003). Although successful completion of projects depends mainly on cooperation between the main actors of a project, problems and disputes have always erupted due to conflicting opinions on various aspects of the project (Abdul-Malak, El-Saadi and Abou-Zeid 2002). The root of these problems is misalignment of interests between the contracting parties (Jensen and Meckling 2001). In cases of back-to-back contracts, which are used broadly in the construction industry, claims tend to propagate along the supply chain. Things aren't made easier since many actors tend to behave opportunistically. As a fact, the idea that the industry has a culture which is opportunistic, prone to conflict and resistant to change is a byword in construction (Rooke, Seymour and Fellows 2003). This opportunistic behaviour does not allow construction companies to develop relationships that support efficient collaboration at the supply chain level. The degree of collaboration and coordination between supply chain actors affects the success of a project (Ronchi 2006).

Claims are present and ever increasing in every construction project, regardless of scale, and they are recognised as a burden for the industry. There is no uniform definition for claims although they may be best described by Kululanga et al. (2001) as "*an assertion of and a demand for compensation by way of evidence produced and arguments advanced by a party in support of its case*". Ho and Liu (2004) point out that many project participants consider them as one of the most disruptive and unpleasant events of a project. Claims may start against one party, but end up affecting multiple parties (Chester and Hendrickson 2005) even at different phases of the project, especially in cases of back-to-back contracting. Research conducted by Zaneldin (2006) shows that the completion of projects is hindered by claims that cause delays in project delivery. In fact, many partnership attempts in the construction industry have failed due to claims. The critically risky aspects of the owners' acts or omissions were associated with their contractual role, especially in relation to disagreement over payment claims and on what constituted variations (Mbachu 2011). Avoiding such situations is not easy as it requires careful study of contract terms, a cooperative spirit and a good understanding of the causes of claims (Semple, Hartman and Jergeas 1994). One way to achieve this is through clever contracting, by proactively anticipating potential change in the planning phase and providing flexible contract mechanisms that enable an effective response (Demirel et al. 2017). Claims are highly affected by the intention and goodwill of the interpreter (the actor considering himself exposed to a realised risk) of the contractual terms. In this context, it is worth noting that a conflict can be managed, possibly to the point of preventing it from leading to a dispute (Fenn, Lowe and Speck 1997). It is typical for contractors to submit claims for cost or time. Not all claims submitted by contractors are accepted by the other parties. Vidogah and Ndekugri (1998) identified eight reasons for rejection of part or all of contractor’s claims, namely (in descending importance): non-entitlement in principle, inadequate information, quantification of claim, lack of breakdown of claim by causes, non-compliance with contractual procedures, inadequate effort at mitigation, validity of architect/engineer’ s instructions, and other grounds. Distribution of control over the various stages of the process for handling claims could influence perceived lack of fairness and the potential for dispute (Aibinu 2006). Third parties are rarely addressed in order to participate in the claims process and boost the feeling of fairness due to the very small profit margins in construction projects.

According to Banwo et al. (2015), events that cause claims can be split into three categories, these being excusable, non-excusable and external. This categorisation allows for an examination of the validity of a claim by the contractor. Non-excusable events are attributed to the other party and do not present a basis for claims, so they are certain to be declined by the contractor and vice versa in the case the contractor submits such a claim. It is common practice for project owners to transfer as many risks as possible to other actors although that doesn’t mean that their exposure to them is necessarily eliminated (Revay 1993). In the case of complex systems such as supply chains, it is impossible to provide an exhaustive description of the rights and obligations of all contracting parties for every possible contingency (Coltman et al. 2009).

Despite the category the claim falls in, the way contractors treat claims is different. What can be observed in the literature regarding claims management are two main trends. On the one hand, researchers propose that claims should be pursued in order to increase contractor’s profitability. For example, Yang and Xu (2011) investigate the situation where contractors bid at low, even beneath cost, and aim at making a profit through claims. Zhou and Tan (2012) go one step further exploring whether taking advantage of claims could also benefit project management efficiency. He and Chen (2010) support that claim opportunities exist throughout the life cycle of a project. This is due to the contract based nature of projects. Opportunism stems from contractual incompleteness (Yates 2002). As Aibinu et al. (2011) concluded in their study, when contingencies occur, which are not fully or only ambiguously covered by the contract provisions, one or both of the parties to the transaction may behave opportunistically by taking actions that increase the transaction cost. Minimising claim causal factors during earlier phases would therefore reduce claims during the construction phase (Sibanyama, Muya and Kaliba 2012). Opportunistic behaviour could either be attributed to cultural and/or financial factors. Ho and Liu (2004) find that economic slowdowns and recessions encourage opportunistic behaviour. On the contrary, Zaneldin (2006) identified that, in the UAE, construction claims are direct results of the on-going growth in the construction industry in the country. Opportunistic behaviour may include a contractor’s intentional ignorance of possible risks involved that may significantly increase costs or decrease profitability (Ho and Liu 2004). This kind of opportunism is criticised when there is talk of changing culture for the better, but it bespeaks a perfectly rational and legal adaptation according to Rooke et al. (2003). Opportunistic behaviour creates adversarial relationships, a problem that plagues the construction industry worldwide, from a local level to an international one.

On the other hand, authors propose claims as a last resort, and only if this is really necessary, as claims conflicts can have a damaging effect on intercompany relations. Claims are sought by these authors as a burden that must be avoided. In their work, Semple et al. (1994) advocate against the use of claims in construction projects because of the adverse effects they have on the industry. Aibinu et al. (2011) propose that, prior to initiating the claim process, actors should consider the financial costs of pursuing claims that may lead to disputes and the impact of these claims on future business prospects with existing or potential clients. Zaneldin (2006) stresses out that it is imperative for the construction industry to develop methodologies and techniques in order to reduce or prevent claims. The wealth generating action of production makes it possible to conceive of economic solutions in terms of win-win scenarios such as partnering (Rooke, Seymour and Fellows 2003).

During a project claims may be submitted by any party. Project stakeholders view claims management from different angles. Opportunistic Bidding Behaviour (OBB), as Mohamed et al. (2011) defined it, was analysed extensively in the current section. Banwo et al. (2015) state that claims management, from the contractor’s perspective, may be viewed through another lens, that of profit maximisation from a supply-chain perspective. This distinguishes claims management as being principally driven by the need to reduce the company’s overheads in an attempt to maximise profit and is analysed in the following section.

In order to better understand the relationship of claims with supply chain management, a non-exhaustive analysis of the types of claims in construction was performed. **Table 18** presents the types of claims recorded in the literature. Most of the types mentioned are in direct relationship with the supply chain of a project. For example, the increase of scope was the main cause of dispute that Semple et al. (1994) identified and almost all other works presented in **Table 18** seem to ratify their find. Increase in scope highly affects the supply chain of a project since new parameters are being added, schedules are shifted and in some cases new subcontractors need to be contracted. Delays which can be directly related to the supply chain, according to Braimah and Ndekugri (2009), are the most often and involve many actors which makes it hard to justify and quantify the effect of each individual item of delay. Contractors must keep in mind that in some cases one type of claim may lead to other types in a later phase of the project (Chester and Hendrickson 2005). Claims management isn’t easy and therefore best practices need to be documented and adopted by companies in the sector in order to avoid long-term effects of bad claim management practices such as late claim identification, ineffective claim management processes and financial losses. Many best practices are documented in the literature in the form of process models.

Process models are widespread in the general literature. Usually they are based on state-of-the-art research but, unfortunately, their adoption by industries is less common. This is also the truth in the case of the construction industry where the effective and widespread adoption and use of process models has been limited, and the benefits span from ambiguous at best to non-existent at worst according to Tzortzopoulos et al. (2005). Numerous reports, for example Egan (1998) and Fairclough (2002), have found that there is a lack of innovation and change in process management practices throughout the industry. This could be due to the fact that there is a lack of effective knowledge management tools and the one-off nature of construction projects. A way to overcome these complex problems is the development and implementation of process reference models, which would allow for a consistent and integrated design and construction process (Kagioglou et al. 2000). Cheung and Yiu (2006) stress out that an efficient claims management approach is essential to prevent disputes from occurring.

Table 18: Claim typology in construction projects

Types	(Revay 1993)	(Zack 1993)	(Semple, Hartman and Jergeas 1994)	(Chester and Hendrickson 2005)	(Zaneldin 2006)	(Moura and Teixeira 2007)	(Hassanein and El Nemr 2008)	(Banwo, Parker and Sagoo 2015)
Acceleration	X	X	X	X	X	X		
Restricted access			X		X			
Force majeure	X		X	X		X		
Increase in scope		X	X	X	X	X	X	X
Loss of productivity	X	X						
Problematic bid documents	X							
Delays		X		X	X	X		X
Measurements and payments				X		X		
Suspension of works						X		
Beginning and ending acts		X				X		
Contract termination						X		
Contract ambiguity					X			
Fluctuation								X
Extension of time		X						X
Ex gratia								X
Different site conditions					X			
Resequencing of work				X				
Defective work				X				
Total cost		X						

The most prominent models found in the construction claims management literature are those of Kululanga et al. (2001) and Abdul-Malak et al. (2002). The prior proposes a typical, oversimplified sequence of tasks for claim management but introduces total quality management tools in order to prevent the occurrence of new claims. The latter describes a more detailed and complex process for claims management that is also accompanied by a related software. Other notable models include works by Moura and Teixeira (2007), a rather simple approach, and by Banwo et al. (2015), an interesting approach that introduces phases during which certain tasks are performed. Finally, in contrast to the previous authors, He and Chen (2010) present a process model for opportunistic claim management, a tactic that is not adopted in the process model described. None of the aforementioned process models make a direct connection between claims and construction supply chain management. This is the gap that the following model attempts to fill.

4.10.2. Claims management process model

The "Claims Management" function contains five processes (**Figure 94**), divided into strategic and operational. On the one hand, strategic processes are executed at the beginning of a project and are updated in case of major changes in strategy or legislation. This ensures that there is certain continuity in the way claims and contract terminations are handled. On the other hand, operational processes are executed as often as needed. Literature treats claims as mainly having a negative hue and the interviews corroborate that relationships are damaged by claims and projects may be delayed. Interestingly, the interviews revealed that claims could also have a positive effect on the project, for example the contractors or subcontractors may identify an opportunity in the plunge of the price of a stock product that may be required at a later stage of the project and submit a claim for its advanced purchase. The function presupposes that behaviours in the construction supply chain are based on mutual cooperation and trust stemming from a partnership environment. It has been proven in cases from the manufacturing industry, such as Wal-Mart (Scott, Lundgren and Thompson 2011), that mutual cooperation is key to successful supply chains. Although construction supply chains are temporary, the interviews conducted revealed that good relationships do exist and, in fact, claims are less likely to escalate to disputes when contracted parties share previous good experiences. The interviews also supported the literature as far as financial climates are regarded, confirming that in times of economic downturns project participants tend to be more distrustful. It is imperative to maintain trusting relationships with other parties since trust enhances the value of the total service provided by the construction supply chain (Xu and Smyth 2015). Thus, opportunistic behaviour is discredited.

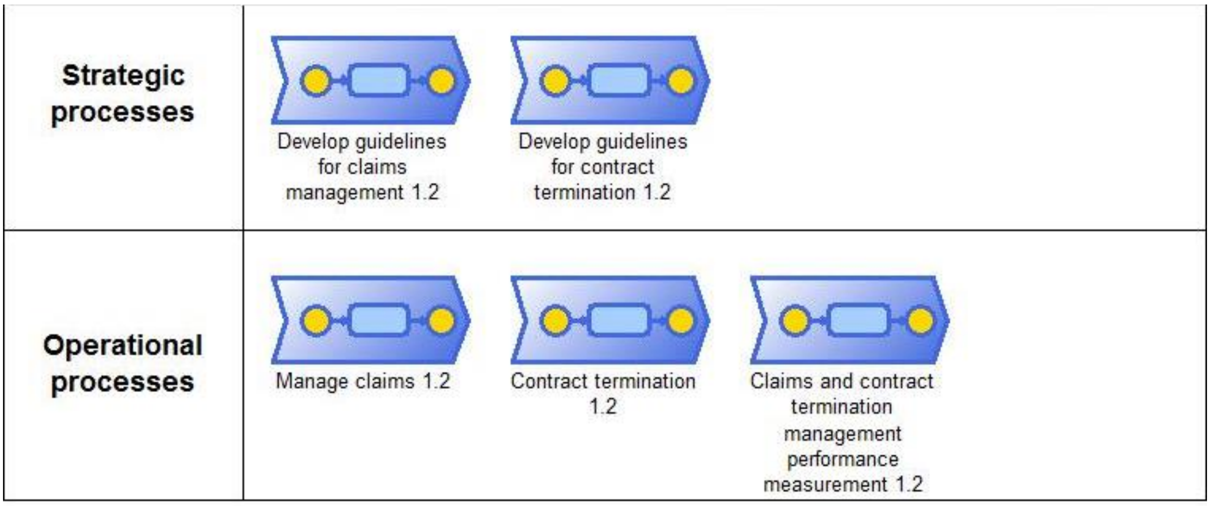

Figure 94: Claims management function tree

4.10.2.1. Strategic processes

There are two strategic processes in the model, namely "Develop guidelines for claims management" and "Develop guidelines for contract termination". These processes can be executed simultaneously or not and the outcome of each process is independent of the other. Each process describes the tasks to be executed in order to develop guidelines that will allow for seamless claim management and contract termination respectively. Strategic processes are of a proactive nature since claims/disputes are unavoidable as Cheung and Yiu (2006) proved in their work using a probabilistic model. The possibility that all potential risks will be foreseen or even mitigated to another party is practically nought. The interviews conducted revealed that there are always claims in construction projects. External factors such as regulations and client requirements (expressed in contracts) interfere with strategic processes. Since one cannot exclude the human factor from the organisational operations, it is imperative that organisational justice is enhanced through project processes and a cooperative attitude is promoted in order to reduce contracting inefficiencies (Aibinu, Ling and Ofori 2011). Finally, contractors must keep in mind that contract cancellations may irreversibly harm relationships between supply chain parties.

The “Develop guidelines for claims management” process (**Figure 95**) should, in an ideal scenario, start before the tendering phase of a new project. As the interviews revealed, some construction companies have strategic guidelines in place for managing claims, but they are usually not described in a clear process fashion. Client and supplier categorisation, according to the sort of relationship the contractor wants to maintain with each one of them, has been developed in the client relationship management and supplier relationship management functions. Based on this categorisation and relative to the specifics of a certain project, the contractor should ‘Set claim strategy for different groups of supply chain parties’. The signed contracts with those parties provide most of the input related to this task. Standard forms of contract pursue different paths in the governance of the process for handling contractors’ claims (Aibinu 2006). Other participants of the project should be evaluated and decisions on how claims against them or from them should be handled. The interviews revealed that supply chain parties are indeed treated differently, depending on the expectations the contractor has for future collaboration. Next, the contractor should ‘Identify possible claims in each phase of the project’. The major phases of a project are: pre-tender, contract formulation, construction and post-construction. According to Sibanyama et al. (2012), claims result from omissions and actions during the former two phases but manifest during the latter two phases. It would be easier to identify possible claims if the contractor consulted a database of claims that have appeared in previous projects, although an exhaustive list would be impossible to create. At this strategic level, it is advisable to ‘Formalise rules to manage claims’ during the project’s life span based on the results of the previous tasks. This task, according to the interviews, involves the decision to submit each claim as a standalone claim or to bundle the claims in order to resolve them collectively in the final phase of the project. Finally, through the ‘Determine rules and mechanisms to minimise incoming claims’ task, the contractor prepares a strategy to defend itself from incoming claims. This could include contract provisions that allow only for a short time frame since an event occurs till the other party submits a claim or mitigating risks upstream the supply chain. The way people are treated (quality of treatment) and the way claims are administered (quality of decision-making) have a large impact on the amount of claims that escalate to disputes (Aibinu, Ling and Ofori 2011).

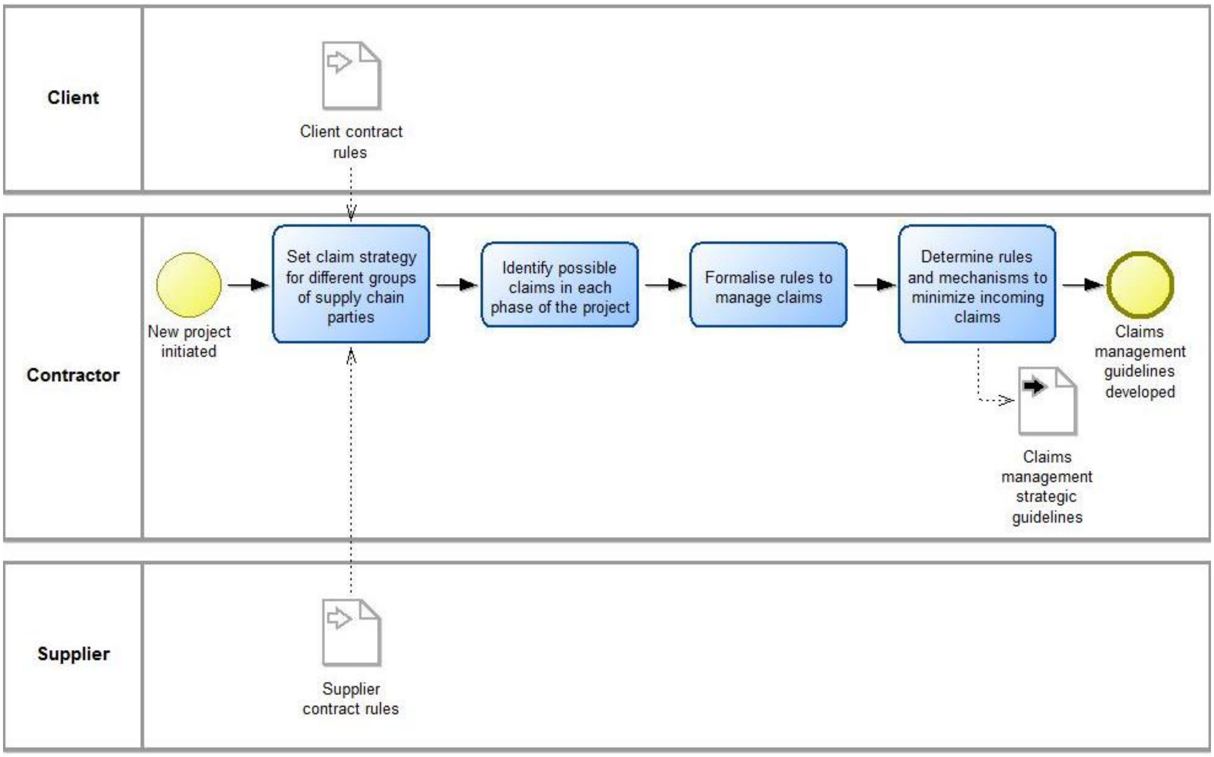

Figure 95: Develop guidelines for claims management

The "Develop guidelines for contract termination" process (**Figure 96**) starts when a new project is initiated. The first task is to 'Determine guidelines for assessing contracts'. Each contract is unique and, although there may be standard contract types, the contracting parties may add clauses to their suiting (as long as they are lawful). There are plenty of factors that should be considered during the assessment of a candidate contract for termination. Value of contract, existence of substitutes, contract termination penalties and relationship with the other contracting parties are just some of these. Contracts may be terminated halfway through execution or even before they start. The 'Determine guidelines for credit/debit approval' task describes how credit/debit for services or products that have been partially offered or remunerated by/to the contractor should be handled depending on the factors mentioned previously. The 'Determine guidelines for contract termination management' task aims at providing an outline of duties that staff in specific organisational positions need to perform in order to have a smooth termination on the contractors side. In addition, these guidelines may be shared with other supply chain parties. 'Determine rules and mechanisms to diminish contract terminations' is a proactive task that aims to provide a toolbox in order to minimise costly contract terminations at the expense of the contractor. Finally, 'Determine rules that will be included in product/service agreements' is a task that is based on the lessons learned from previous contract terminations. It aims to provide clauses that should be proposed for inclusion by the contractor during the negotiation phase.

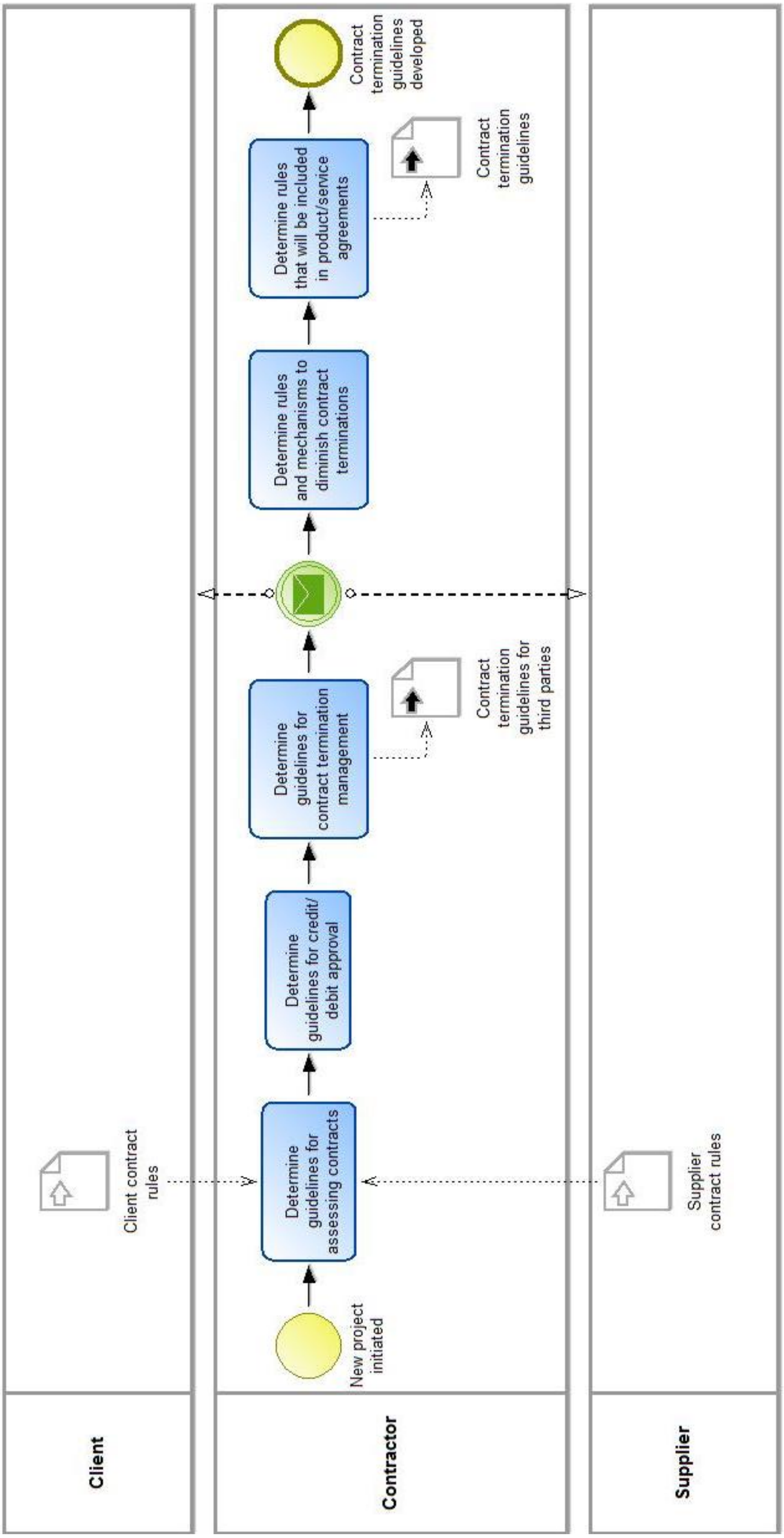

Figure 96: Develop guidelines for contract termination

4.10.2.2. Operational processes

There are three operational processes in the model, namely “Manage claims”, “Contract termination”, and “Analysis of claims and contract termination data and performance measurement”. These processes are not independent of each other and their typical relationship would be the one seen in **Figure 97**. Each process describes the sequence of steps that are executed reactively to the occurrence of disruptive events. In the “Manage claims” and “Contract termination” processes, attention must be paid to exaggerated costs that attempt to bring settlement costs up (Chester and Hendrickson 2005).

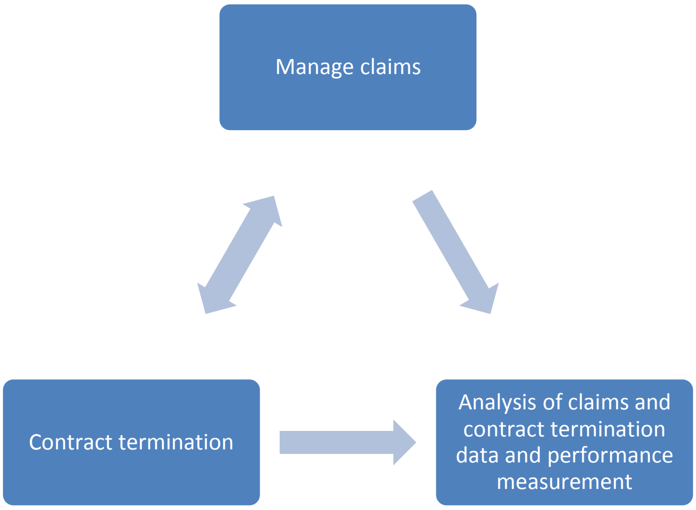

Figure 97: Operational processes interdependencies

The first process, “Manage claims”, as seen in **Figure 99**, may be initiated by two different events. Either the contractor initiates a claim against another party in the supply chain, or another party initiates a claim against the contractor. In the first case, the contractor initiates the claim process when it is perceived that a triggering action on the part of the owner or engineer has taken place (Abdul-Malak, El-Saadi and Abou-Zeid 2002). The first sub-process is to ‘Identify the claim’. As the interviews revealed, the contractor executes three tasks simultaneously, namely ‘Monitor contract specifications’ that includes careful analysis of designs and verbal specifications included in the contract, ‘Monitor market conditions’ that includes value engineering, and ‘Monitor project outcome’ that includes quantity surveying (based on the bill of quantities) and quality assurance, as seen in **Figure 98**. Through this continuous monitoring the contractor may ‘Identify claimable deviations’. These deviations may include differences in the project outcome compared to the contract specifications, opportunities for cost reductions, speedier depreciation with the instalment of systems that did not exist during the design phase, or schedule related issues.

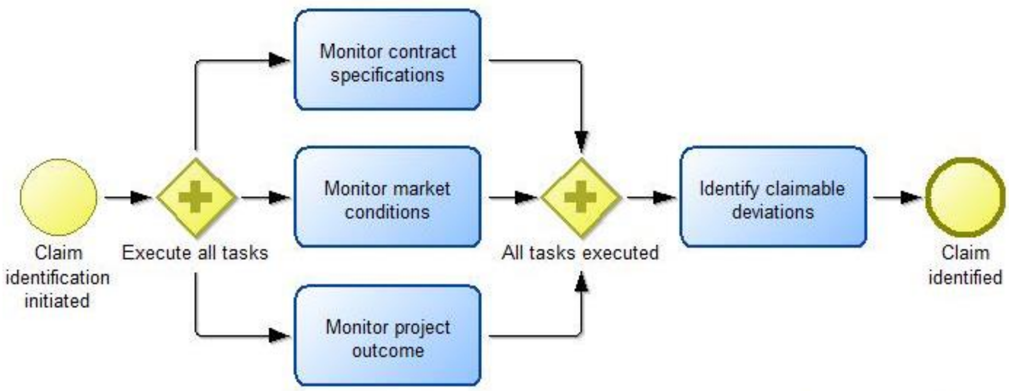

Figure 98: Identify claim sub-process

Next, it is necessary to 'Determine the effect of the claim'. As Abdul-Malak et al. (2002) state:

> "…*if the effect on the program and budget can be directly assessed after the occurrence of the cause for a claim, there will then be no continuous effect. On the other hand, if the consequences resulting from the claim are not foreseeable or cannot be measured at the time the contractor notifies the owner, the claim in this case has a continuous effect.*"

During this task, the contractor must also estimate the potential recovery. The contractor must 'Notify third party of claim intention', preferably in a non-adversarial manner (Kululanga et al. 2001), in order to abide by the usual contract provisions that require such action. It is to the contractor's benefit, in order to increase the chances of a successful claim, to be thorough during the 'Collect appropriate claim documentation' task. Poor documentation can cause the loss of a favourable position in the claim and lead to legitimate claims being denied. This documentation, according to Yang and Xu (2011), must include general parts, contract citations, calculations of financial claims and time claims, and claim evidence. The interviews revealed that the most important document to support a claim is the worksite diary. The importance of keeping good site records, especially for delay related claims was highlighted by Scott (1990). The interviews also revealed that dated and signed correspondence between project participants can also provide backup to any claim. Other items that may be used as documentation, such as images, invoices and impacted schedules, may be used by any party to support their claim. Once the claim documentation has been collected and the case has been supported as best as possible, the task 'Present claim to third party' can be executed. The claim file is presented to the other party in order to allow time for study before it is discussed. In an attempt to escape adversarial practices of the past, the contractor should 'Examine alternative solution for claim management'. In the second case, the contractor will 'Receive claim notification' from another party. The contractor has to wait until the other party compiles the claim documentation in order to 'Examine claim documentation' and rule its veritableness. This may be a claim for compensation from the client or a claim for extra time or payment by the subcontractor. The contractor has to ascertain what kind of event, according to the categorisation by Banwo et al. (2015), lead to the claim. The rejection may occur due to poor documentation by the other party and, in some cases, the claim may be resubmitted if the contract conditions allow it. In the case of a non-excusable event, the contractor performs the task 'Reject claim' which includes composing the reasoning of the rejection and the notification of the other party that no compensation will be repaid. In case of an excusable event, the contractor must ‘Examine alternative solutions to payoff’ in order to maintain his profit margins intact and his relationship with the other parties at a good level. In both previous scenarios the next steps are common. The contractor must ‘Prepare negotiation’ in order to: “*(1) ascertain that all information is current and complete; (2) minimize the scope of negotiation beforehand so that insignificant points should not precipitate a violent argument and disrupt progress; (3) know one’s weaknesses and try to utilize weak points by conceding them in return from the other party; (4) foresee problems; and (5) anticipate the opposition’s next move*” (Kululanga et al. 2001). The next task, ‘Negotiate claim’, is probably the most important task in the whole process since it is of a make or break nature. During negotiation, there is a tuple of factors that may affect the outcome such as perceptions of the parties about their interactions (Aibinu, Ling and Ofori 2011), the subjective nature of the existence of a claim right (Ho and Liu 2004) and the selection of a resolution channel (negotiation, mediation, arbitration or litigation) (Zaneldin 2006). If negotiation fails, the next task is to ‘Manage dispute’. This includes the participation of a third party (e.g. court of law, arbitration), depending on what the contract prescribes. If negotiation leads to a resolution, the following task is ‘Resolve claim’. It includes the procedural work to be completed once a negotiation has been concluded. Finally, in the case that an alternative solution has been reached, the two parties must ‘Update contract with alternative arrangement’. The interviews revealed that the chances of alternative solutions increase when there is mutual understanding, goodwill and a good relationship between project supply chain parties. In the case where an alternative solution has not been found, the contractor must ‘Issue a mandate for claim payoff’ that either regards a demand (monetary or time relayed) from the other party or an obligation for the other party.

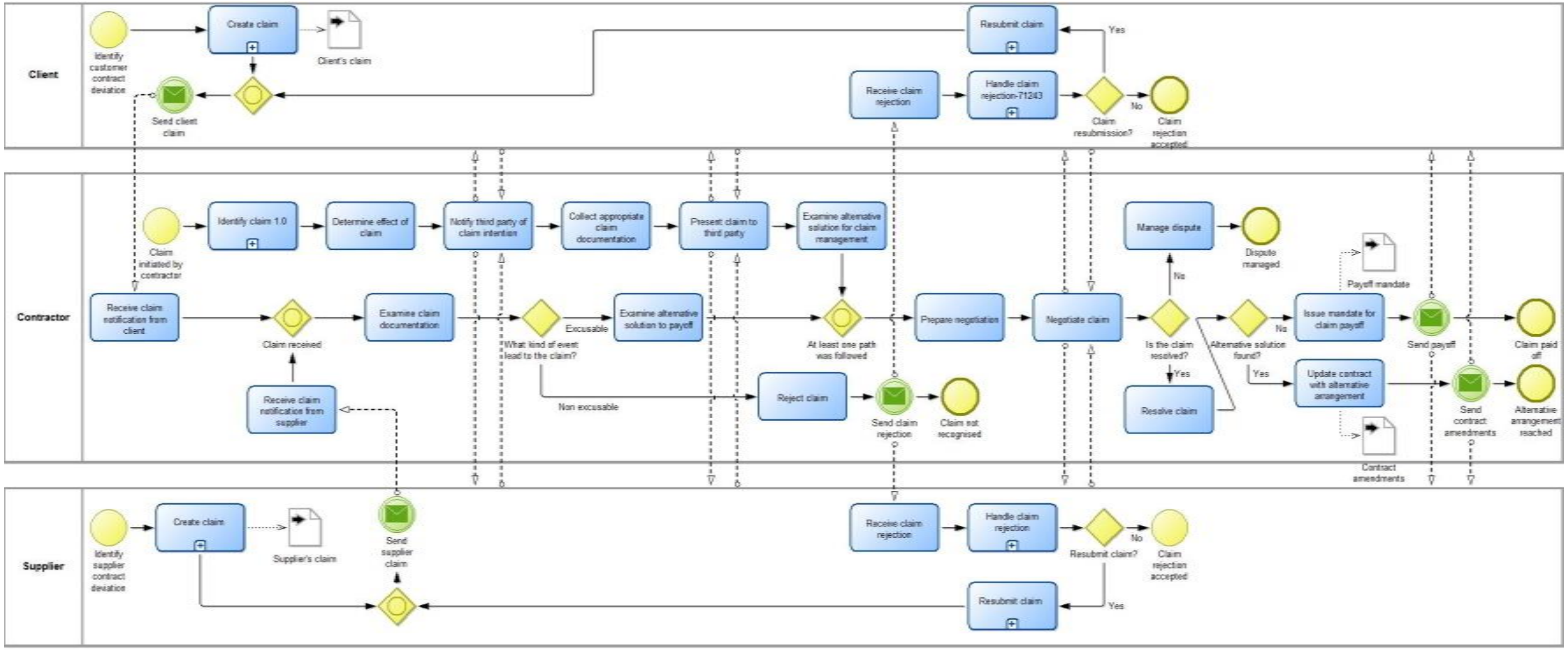

Figure 99: Manage claims

The second process, “Contract termination”, as seen in **Figure 100**, despite not being executed very often since it usually constitutes the last resort of a dispute, can also be initiated by two different events. Either the contractor receives a request from a third party to terminate a contract or, the contractor initiates the contract termination through the ‘Issue mandate for contract termination’ task. In both cases, there is a single sequence of tasks that follows, the first of which is ‘Determine contract termination causes’. Although contract terminations usually occur after a claim that leads to litigation (which means that the cause is already known), in some cases unforeseen reasons may lead to contract terminations even before the physical part of a project is initiated. The next task is to ‘Check termination guidelines’. The guidelines have been set in the second strategic process and provide for many different cases. A contract termination affects many departments of a company; it is not solely extra work for the legal department. This makes ‘Notify interested departments of termination’ the next task. Each department should check the termination guidelines for the parts of the contract that concern it and estimate the impact of the termination on its operations. A sum of these estimates would give an idea of the real cost (not only monetary) of the contract termination. The ‘Check for contract termination clauses’ task aims at covering possibilities of remuneration for the lost profits. The interviews revealed that the contractor should then ‘Provide ‘Make good’ time’ to the other party (or may be provided with ‘Make good’ time by the other party), in order to rectify misalignments with the schedule or other unresolved major issues. In a spirit of cultivating trust and improving relationships between supply chain actors it is highly recommended to execute the ‘Check for need for settlement’ task. This may lead to new claims and the activation of specific contract clauses. The need to maintain good relationships with specific parties could depend on the availability of adequate competitors in the specific sub-market (Stamatiou et al. 2016). The final task, ‘Check course of termination’ is procedural and is intended to create intermediate reports on the progress of the contract termination.

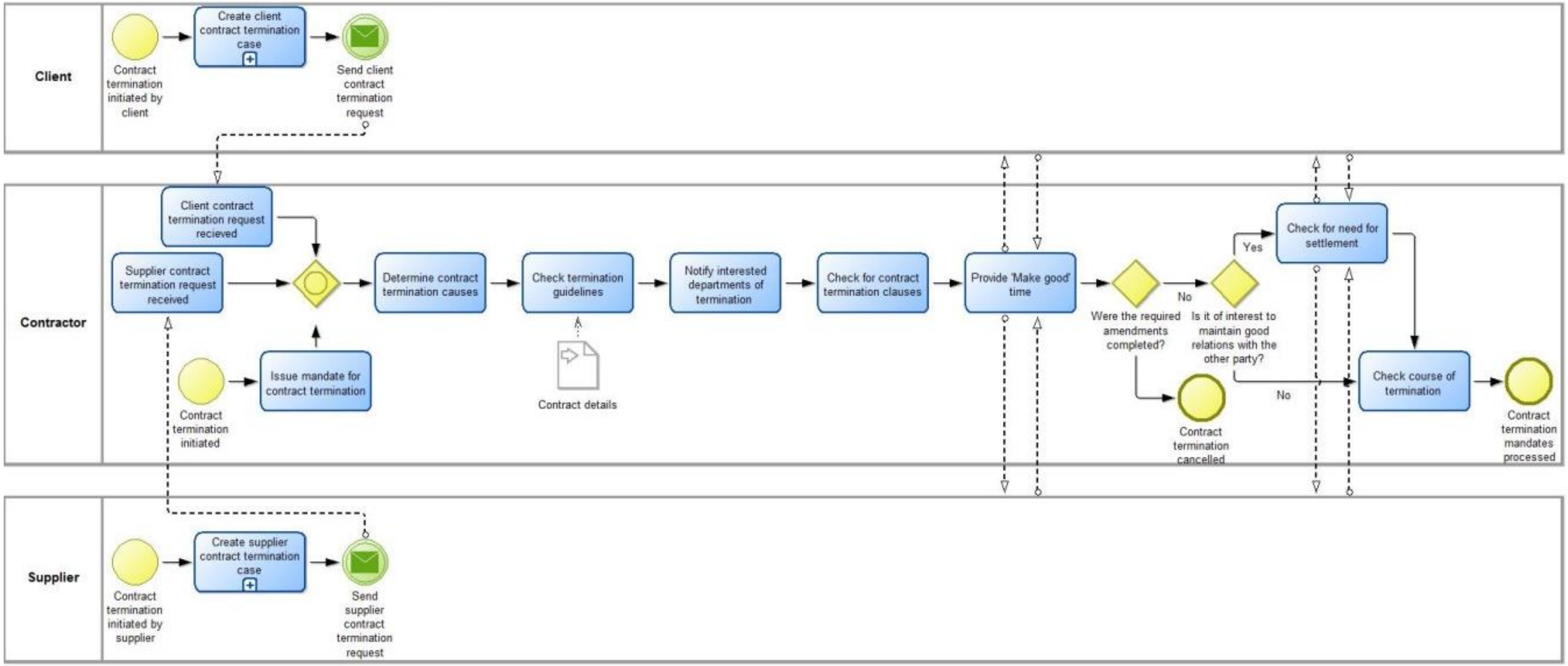

Figure 100: Contract termination

The need for a structured instrument for auditing construction contractors' claim process for the purpose of reducing time and cost increases cannot be overemphasised (Kululanga et al. 2001). The "Claims and contract termination management performance measurement" process (**Figure 101**) is the last operational process of the claims management function. It is in line with the directory for the construction industry composed by Egan (1998) that moves companies to the development of management measuring tools as a mean towards modernising the industry. The interviews revealed that the majority of construction companies do not use KPI to monitor the claims related processes. Effective monitoring and registering of claims enables managers to identify opportunities for productivity improvement. The first task is to 'Record and classify data from claims and terminated contracts'. A unified grouping system across projects will allow for knowledge generated in any project to be concentrated and used whenever required. In an ideal case, this could be an international system (Moura and Teixeira 2007). Next, the 'Monitor claims and contract termination management performance indicators' task is executed, where strategically selected performance indicators are calculated. These indicators are part of either a robust but concise measuring system that the company designs to meet their exact needs, or is an adaptation of a verbose system available by consulting firms. This measuring system could, for example, contain indicators such as claim cost to earnings, claims successful to claims submitted and other useful ratios. As part of a knowledge management strategy, the 'Analyse effects of claims and contract termination' task is critical in order to support future claim decisions. The effect of a specific claim and claims in total on intercompany relationships and transactions, project performance and intra-company performance should be examined. As Kululanga et al. (2001) propose, a total quality management system could be implemented in order to support such an analysis. The task 'Detect opportunities to avoid claims and contract termination' aims at two things: primarily to use the knowledge base in order for the contractor to minimise claims against him or precarious contract terminations and, secondarily, in the spirit of a cooperative and goodwill stance towards other actors of the supply chain, to avoid making small scale claims that only harm relationships and do not necessarily add towards profitability. Finally, the last task to be executed is 'Determine performance improvement objectives'. In this task, managers compare performance indicators against strategically set targets in order to examine performance shortfalls, their causes and areas for improvement. In some cases (e.g. partnerships), the relationship with the third party may lead to the sharing of KPI data in order to satisfy jointly set goals.

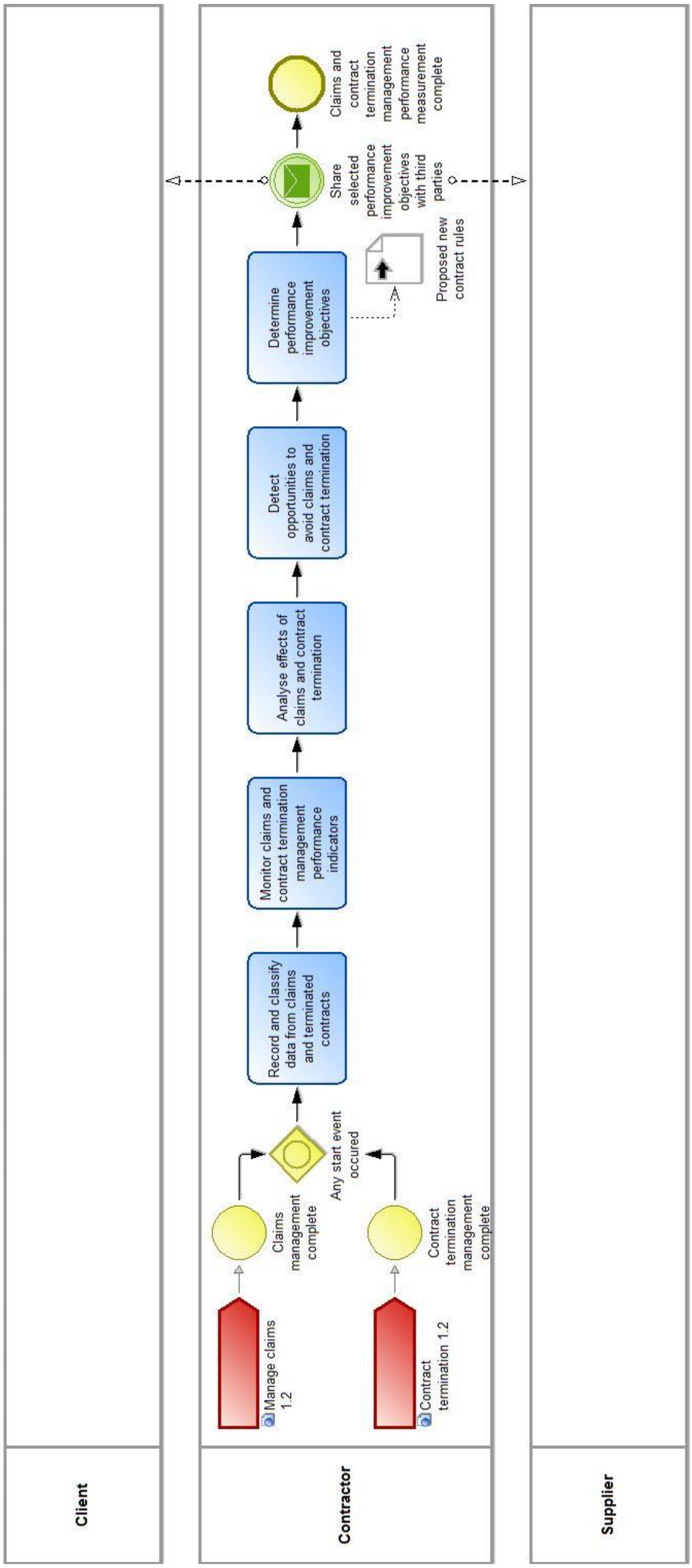

Figure 101: Claims and termination management performance measurement

4.11. Process interrelationships

The functions of the reference model described in this chapter do not exist in isolation; rather they are interrelated. This section of the reference model describes the level of interrelationships between the reference model functions. Interrelationships relate to the density of information exchanged between functions. This concept has been examined before in reference modelling by the Global Supply Chain Framework (e.g. Croxton et al. 2001), albeit in a connectivity manner. In this dissertation, a qualitative method is used to depict the level of interaction density between the reference model's functions. A three level scale is used, namely high (H), medium (M), and low (L) and all of the relative information is depicted in **Table 19**.

Table 19: Level of process interrelationships

	SCMS	CRM	PDC	SRM	KPI	DM	WPM	CFM	CM
SCMS		H	H	H	H	H	H	H	H
CRM	H		H	L	H	M	L	L	H
PDC	H	H		H	H	L	H	M	M
SRM	H	L	H		H	M	H	H	H
KPI	H	M/L	M/L	M/L		M/L	M/L	M/L	M/L
DM	H	H	M	H	H		M	L	L
WPM	H	L	H	H	H	L		H	H
CFM	H	L	L	H	H	L	H		H
CM	H	H	L	H	H	L	M	M	

SCMS: Determine supply chain management strategies, CRM: Client relationship management, PDC: Project development and commercialisation, SRM: Supplier relationship management, KPI: Develop key performance indicator framework, DM: Demand management, WPM: Work package management, CFM: Construction flow management, CM: Claims management

The "Determine supply chain management strategies" function has a high level of interaction with all other functions in the model as it provides the strategies that govern decisions, processes and aims of each function. All other functions also have high interaction levels with the specific function as they provide feedback from the implementation of the selected strategies and help in their adjustment over time.

The "Client relationship management" function has a high level of interaction with the "Project development and commercialisation", "Develop key performance indicator framework" and "Claims management" functions. Identification of client requirements and contracting provide inputs for both the PDC and CM functions, where the measurement of performance through selected performance indicators provides input to the KPI function. The "Demand management" function receives medium level of input from the CRM function as on-going projects and long-term client relationships provide some input for demand forecasts without being the sole sources of information. The "Supplier relationship management", "Work package management" and "Construction flow management functions" receive lower levels of input from the CRM function. Clients may, in some cases, select specific subcontractors to involve in the construction process but they do not dictate interaction between the contractor and these subcontractors. As for the WPM and CFM functions, input from the CRM function may, for example, relate to minutes from meetings conducted.

The "Project development and commercialisation" function has high levels of interaction with the "Client relationship management", "Supplier relationship management", "Develop key performance indicator framework", and "Work package management" functions. Transactions during the development of a new project are high both with clients and suppliers as designs are changed to fit client requirements, suppliers are invited to provide their input and the project design process is finalised and work packages are determined. “Construction flow management” and “Claims management” functions receive a medium level of input from the PDC function as designs are used both during the construction process and in order to settle claims. Finally, the “Demand management” function receives low input from the PDC function.

The “Supplier relationship management” function has high interaction levels with the “Project development and commercialisation”, “Develop key performance indicator framework”, “Work package management”, “Construction flow management”, and “Claims management” functions. Key suppliers will be required to provide input during the project design phase and, when the project is under construction, will be providing their products or services in a timely and efficient manner. Claims will be formed in cases of deviation from the required work, quality or costs. All the data produced during the SRM processes will be handled in KPI function. SRM processes will produce a medium level of input for the “Demand management” function, mainly in the form of forecast input data. Finally, the “Client relationship management” function receives low level input from the SRM function.

The “Develop key performance indicator framework” function provides a high level of input to the “Determine supply chain management strategies” function. Performance indicators are the main monitoring tool for the success of the selected strategies. All other functions will receive medium or low input from the KPI function, depending on whether there is/will be a process maturity analysis program or not.

The “Demand management” function provides high levels of input to the “Client relationship management”, “Supplier relationship management”, and “Develop key performance indicator framework” functions. Relationships with other supply chain parties may bear more weight if there is a predicted drop in demand. All the processes of the function will provide input to the KPI function upon their execution. DM will provide the “Project development and commercialisation” and “Work package management” functions with medium levels of input as predicted levels of demand influence the attention given to new project development and the execution of current projects. Finally, the “Construction flow management” and “Claims management” function receive low levels of input from the DM function. In cases of low demand prediction the contractor may be more prone to claims in order to sustain profit levels.

The “Work package management” function provides high levels of input to the “Project development and commercialisation”, “Supplier relationship management”, “Develop key performance indicator framework”, “Construction flow management”, and “Claims management” functions. Previous experience with work packages may play an important role during the design of new work packages in projects under development. In addition, suppliers and work site operations are all guided upon the work packages under execution and any deviation may result in receiving or filing a claim. All processes in the function provide input, upon execution, to the KPI function. “Client relationship management” and “Demand management” functions receive low levels of input from the WPM function. These mostly concern the completion of a work package and any relative documents that have to be reviewed by the clients, along with a list of work packages awaiting completion.

The “Construction flow management” function provides high levels of input to the “Supplier relationship management”, “Develop key performance indicator framework”, “Work package management” and “Claims management” functions. Suppliers receive input regarding the work on site that has been scheduled and the requirements according to the contract. Work packages are updated based on the weekly progress on the work site and claims are registered. All CFM processes provide input to the KPI function upon execution. The “Client relationship management”, “Project development and commercialisation”, and “Demand management” functions receive low levels of input from the CFM function. This input is mostly related to progress updates, problems on the site, changes and design problems.

Finally, the “Claims management” function provides high levels of input to the “Client relationship management”, “Supplier relationship management”, and “Develop key performance indicator framework” functions. Claims, especially if the other side is rather aggressive, will change the contractor’s stance towards the relationship with that specific side. In addition, if other parties have systematically not fulfilled their side of the agreement, the contractor may decide to change his stance. Upon execution of CM processes the KPI function receives high rates of data. There is a medium level of input from the CM function towards the “Work package management” and “Construction flow management” functions. This relates to changes that have been accepted after a claim or the impact of other claim related outcomes. The “Project development and commercialisation” and “Demand management” functions receive a low level of input from the CM function. This is mainly in the form of knowledge acquired from the resolution of claims and information regarding market segments that may interest the contractor for future work.

5. Discussion and interview analysis

5.1. Discussion

Construction has plenty of potential for improvement. In order to reach this improvement, it has to move away from adversarial relationships towards collaborative ones based on the principles of supply chain management (Love, Irani and Edwards 2004). Supply chain management in the construction industry was slow to take off (Aloini et al. 2012B). The particular context of temporary multi-organisational relationships (Cheng, Law, Bjornsson, Jones and R. Sriram 2010), the high complexity and uncertainty in which the production system operates (Fearne and Fowler 2006), the high influence of the client in the final product (Pesämaa, Eriksson and Hair 2009), process fragmentation (Briscoe and Dainty 2005), and the difficulties in the management of large networks of suppliers (Briscoe, Dainty and Millett 2001) combined with adversarial relationships have impeded the adoption of construction supply management. In practice, despite the development of both formal and informal partnering arrangements (Briscoe and Dainty 2005) closer relationship development and processes integration are difficult to realise (Bankvall et al. 2010). The development and implementation of collaborative working methods are unyielding without the integration of subcontractors in the process (Hughes et al. 2006). In order to resolve supply chain management problems, contexts such as relational behaviour, trust and focus in the long-term will play a critical role (Aloini et al. 2012A). Successful implementation of supply chain management depends on the following factors (in descending importance): customer focus, process management, continuous improvement, innovation, supplier partnership, people development and involvement, leadership, consistency of purpose, leadership and management, finance, skills and expertise, culture of the recipient organisation, and positive cash flow (Ozols and Fortune 2012). As customer focus is high, process management is the most important factor to focus on. The literature is lacking badly in holistic approaches to supply chain management (Barker, Hong-Minh and Naim 2000). These approaches have the potential to lead to many benefits that must be potentially value-enhancing for all the participants within the network (Aloini et al. 2012A).

Currently, enterprises aim at dynamic flexibility in order to handle shifts in demand and technology within their existing supply chains, but the future is with structural flexibility that builds flexible options into the design of supply chains (Björnfot and Torjussen 2012). The literature has identified this need and is moving towards the development of conceptual frameworks (mainly at a strategic decisional level) (Aloini et al. 2012B). The role of business processes modelling in achieving the required interoperability and agility is highlighted by the importance of business processes (Gayialis et al. 2015). Process approaches emphasise the fact that processes usually cross the organisational "functional" boundaries and an end-to-end view of the process is required in order to make improvements; system approaches emphasise the fact that processes do not exist in isolation but they interact with each other in a network; continuous improvement is based on the PDCA (Plan, Do, Check, Act) improvement cycle (Coletta 2011). These are all characteristics of the reference model described in this dissertation. Furthermore, the reference model complies with the following requirements: planning and management of supply chains requires proper specification of participating members and their relationships (Cheng, Law, Bjornsson, Jones and R. Sriram 2010); it is represented in a general, reusable and applicable form, so that specific application models can be created by adaptation and modification (Klingebiel 2008); it does not provide a ready-to-implement model but a solid starting point that reuses community knowledge obtained from addressing similar requirements in comparable organisations (Svensson and Hvolby 2012); and uses standards for alignment of systems, quality assurance and innovation as well as risk reduction (Bankvall et al. 2010, Elliman and Orange 2000, Sánchez-Rodríguez et al. 2006). In addition, the innovation of the reference model is the merging of both single project and portfolio processes in a single model. Thus, as proposed by Thunberg and Persson (2014), it encourages construction companies to start measuring their supply chain efficiency and compare with other companies in the construction industry.

Construction companies, just like all companies, need to formulate a general strategy for their operations to ensure their survival. An integral part of this strategy relates to supply chain management strategies. The selection of the market segment to target, the positioning and channels used to access the markets, and the scale and scope of activities (Day 1990) are part of complex strategy that has to be detailed in order to identify individuals, companies or organisations that the company wants to interact with. It is important to create a strategy that has a multi-project approach and takes advantage of repetitive working to improve strategic thinking, increase innovation and supports continuous improvement (Vrijhoef et al. 2014). Traditional methods of interaction between the contractor and its supply chain partners cause problems with the management of the supply chain and the integration of processes (Briscoe and Dainty 2005). Considerations on managerial, organisational, relational and technological issues when strategizing play an important role (Palaneeswaran et al. 2003). Three types of supply chains (temporary, framework-specific, company strategic) have to be managed by the contractor (Dubois and Gadde 2000) at the project, firm, and relational level across many projects simultaneously (Håkansson and Jahre 2004). This creates limitations and interdependencies in the supply chain that have to be examined strategically. All three competitive strategies (differentiation, cost leadership, focus) proposed by Porter (1985) have been found in the construction industry (Dikmen and Birgönül 2003, Price and Newson 2003). The selection of a specific strategy can lead to competitive advantage but it is very hard to gain results if companies only devote their attention to specific attributes of the strategy (Oyewobi, Windapo and James 2015). The first pristine view of the selected strategy is seen through the contractor’s decision to bid. The motives and the price tag accompanying each bid reveal the strategy followed. The next step, after winning the tendering process, is to select the parties that will be involved in the project and the type of relationship that will describe interactions with each party. Continuity, complexity, symmetry and informality (Håkansson and Snehota 1995) are the variables that, when analysed, will lead to one of four relationship types (transactional, series of transaction, project collaboration, long-term strategic partnering) (Pala et al. 2012). Each relationship requires a different level of integration and the dimensions of each integration are strength, scope, duration, and depth (Eriksson 2015). Interactions between companies could be simple or complex depending on the tasks required by each side. The relationships developed by the interactions have to be supported by appropriate tools, processes, procedures and motives that will provide a smooth experience (Pala et al. 2013). One of the tools that can support modern relationships is information technology. Such technologies support supply chain interactions by automating tasks, facilitating collaboration through processes and enabling information flows and their adoption depends on the characteristics of each supply chain relationship and their interfaces (Benton and McHenry 2010, Hadaya and Pellerin 2010). There is a wide range of available solutions that can fit any supply chain relationship (Madenas et al. 2014) and fit each company’s requirements. Such systems can be used to manage scarce resources and variables that have heavy impact on the successful implementation of strategy (Ahlemann 2007). Contractors tend to use different tools with each partner and not every partner uses the same software solution to manage their data. This means that incompatibilities are abundant there is a need for process change that permits trouble-free data exchanges (Vaidyanathan and Howell 2007). Information tools are at the core of collaborative attempts to improve value generation in the sector (Poirier, Forgues and Staub-French 2016).

Collaboration in project execution is unavoidable, since contractors lack the ability, resources and expertise to execute all required tasks. Streamlining operations vertically (between business units) and horizontally (along the project supply chain) will lead to operational efficiency (Vaidyanathan and Howell 2007). Integration of processes, a part of operations integration, though is hard to achieve since there is no trust between partners. Developing closer relationships is a way to improve trust and allow integration to go forward smoothly. Integration requires dedication to detail and timing (Gil 2009). In addition, economic conditions that motivate parties to integrate are required (Bresnen and Marshall 2000) along with a comprehensive and systemic view (Eriksson 2015). It is a common notion that collaboration is an endpoint rather than an evolution in relationships (Bedwell et al. 2012), but this view limits the effects of a closer collaboration on performance (Gadde and Dubois 2010). Collaboration can be short-term or long-term. Long-term collaborations offer greater benefits to involved parties (Meng 2013). Collaborative relationships are hard to build and maintain, thus at an early stage a limited group of parties, such as key suppliers, should be targeted (Brown et al. 2001). Key suppliers should be provided with relational contracts that allow the growth of trust through transparent distribution of responsibilities (Lahdenperä 2012). Partnering is a collaborative approach to relationships in the construction supply chain. The contractor may partner with the client or key suppliers for a single or multiple projects at one time or in the long run. It is based on better process integration along the supply chain and promotes collaborative and less hierarchical relationships (Crespin-Mazet, Ingemansson Havenvid and Linné 2015). The move from traditional adversarial relationships to collaborative ones requires a holistic and systemic change in variables such as structures, processes and attitudes (Eriksson and Pesämaa 2007). Once a company experiences its first successful partnering attempt, partnering becomes the preferred method of collaboration (Crespin-Mazet, Ingemansson Havenvid and Linné 2015). There is no golden rule to partnering that will make it successful at all attempts. It is more of a learn-by-doing process (Bennett and Jayes 1998) and requires the early commitment of management resources (Kaluarachchi and Jones 2007). Partnering requires both hard and soft skills to succeed, but soft skills bear more weight in the success of the undertaking (Briscoe, Dainty and Millett 2001). Partnering allows for increased levels of learning (Love et al. 2002) and entering such agreements with suppliers is thought to resolve many of the long-lasting problems of the construction industry (Naim and Barlow 2003). Partnering allows designers and contractors to innovate, contrary to traditional price-based contracts (Love, Irani and Edwards 2004). Despite the benefits of partnering, there are some pitfalls that companies have to be aware of. Partnering is not a remedy for all relationship problems and it cannot be used in every project or with every party (Jashapara et al. 1997, Thompson and Sanders 1998B, Bresnen and Marshall 2000, Ng et al. 2002, Eriksson 2010). Partnering should be used wisely and this includes the selection of a suitable extent of cooperation in every relationship (Bresnen 2007). Actors must adjust and direct their activities and resources over multiple supply chains and construction sites and the interdependencies between these parameters have important implications on the coordination of partnering attempts over a single project (Bankvall et al. 2010).

The “Determine supply chain management strategies” function is comprised of three processes. Based on Porter (1985) the three processes describe the strategic decisions for management, support and core construction supply chain management functions. The first process describes strategies for the contractor to interact with its environment (clients, suppliers, and new project development), the second process describes strategies for the development of the support processes such as performance measurement, and the third process describes strategies related to the management of demand, work packages, construction flow and claims. The process description is accompanied by references to recorded best practices in the literature and pitfalls to look out for. The model does not adopt or propose specific strategies since this is a decision to be made by each individual company. The model attempts to present a holistic and generic approach to determining supply chain strategies in the construction industry. Finally, it is important to remember that in any case “*the real strategy of an organization is what the organization does and not what is written in brochures*” (Romano, Grimaldi and Colasuonno 2016).

Clients are the life source of any organisation and construction organisations are no different. But, unlike other industries where organisations have identified and recorded processes related to the management of relationships with their clients, construction organisations lack such structured management tools. Clients of construction organisations are different to the clients of a mainstream manufacturing organisation. Construction organisations find themselves with many ways to define their client (Higgin and Jessop 1965, Franck and Zeisel 1983, Hillebrandt 1984, Cherns and Bryant 2006, Edmondson 1992, Masterman and Gameson 1994, Darlington and Culley 2004, Boyd and Chinyio 2006) a fact that impedes the adoption or creation of a framework. Tzortzopoulos et al. (2009) propose a taxonomy for clients that provides construction organisations with a tool they can build on in their attempt to define their clients. Clients in the construction industry are characterised by complexity in their structure, decision making and requirements (Briscoe et al. 2004, Bertelsen and Emmitt 2005, Preece et al. 2015) but their requirements of projects and contractors have risen in recent years (Dulaimi 2005). Clients’ knowledge of construction practice can range from non-existent to very sophisticated (Preece et al. 2015) and their level of involvement in the project is a key driver for performance, innovation and supply chain integration (Briscoe et al. 2004). Factors affecting the level of client involvement are: client's organisation structure, client's knowledge and experience in construction, authorities of client organisation levels, and personal characteristics of client’s personnel involved in the project (Arabiat, Edum-Fotwe and Mccaffer 2007).

Contractors face a high level of uncertainty when entering a relationship with a client. Client behaviours that contractors have to manage include lack of a universal approach to contractor selection, long-term confidence based on the results of pre- qualification, dependency on tender sum in tender evaluation/final selection methods, and over-reliance on subjective analysis (Holt, Olomolaiye and Harris 1995). Client goals differ with each client and project leading contractors to the need to develop a diversity of management approaches in order to achieve the goals (Skitmore and Mills 1999). Contractors must develop an understanding of the client’s expectations and diffuse it through the personnel that will manage the specific client. Failing to do so will create a bad experience for the client, thus diminishing prospects of future work with the specific client (Maloney 2002). This means that doing business with clients might come with a cost for the contractor in monetary, reputation, or other terms. Contractors have to learn to do business with clients keeping client satisfaction in mind in order to maintain work prospects or attract new clients via word of mouth. Contractors must develop tracking skills and high responsiveness to identify changing market needs (Dulaimi 2005).

Cooperation between the client and the contractor is a critical factor of project success. Despite being a buzzword in the literature, it is actually much more difficult to achieve in practice. Failures will occur, thus conviction and perseverance in implementation is required (Boes and Dorée 2013). The nature of relationships has a major impact on the project and it is required, by both parties, to align their interests and develop a collaborative relationship in order to avoid escalation of conflicts, enhance knowledge transfer, improve problem resolution, and complete projects successfully (Suprapto et al. 2015). Cooperation problems stem from traditional project procurement methods used by clients. Client behaviour and the contractor's response set the stage for cooperation level and quality during the project. On the contractor's side, how well competitive pressures and contractual arrangements are managed will directly affect the climate of cooperation, likewise on the client's side, these pressures that may be managed by the client or a representative, have the exact same effects (Boes and Dorée 2013). In many approaches, contractors offer a service to the client and team-working, along with patience, are critical for cooperation to be smooth (Corley et al. 2001, Maloney 2002). There are many types of cooperation that can be applied to different types of projects depending on their characteristics. In all cases, the best result will come when the client engages in the construction process and the contractor keeps him well-informed during the project (Rowlinson 2005). Information flows are the spine of cooperation and promote coordination and collective action along the project supply chain, create common backgrounds among the organisations and their personnel and support mutual understanding (Isatto and Formoso 2011). In the bottom line, projects are created, realised, used and demolished by people whose attitudes affect projects more than it is realised. As it is all down to people, two emotional parameters have to be considered: trust and satisfaction. Trust is the main factor affecting project governance mode selection and effectiveness of control mechanisms (Manu et al. 2011). Trust is affected by many parameters, such as past experiences and level of familiarity with the other party. The benefits of building trust between clients and contractors are multiple (Mayer, Davis and Schoorman 1995, Mayer and Gavin 2005, Talay and Akdeniz 2014, Xu and Smyth 2015, Manu et al. 2011), including the main concern of all clients; cost performance (Gulati and Nickerson 2008). Client satisfaction is mostly considered at the end of a project. There are many parameters that affect client satisfaction and concern both parties of the exchange. These include contractors not being a part of pre-tendering, client experience/knowledge of building, client's ability to grasp and describe stakeholders' needs and requirements, procurement regulations (mainly in public clients), contract types, tender acceptance and document approval, work-site coordination, and delivery (Engström, Sardén and Stehn 2009). A satisfied client is more likely to return for future works. In order to benefit from both trust and satisfaction, there is a need to develop client relationship management systems.

Client relationship management systems are currently implemented in many industries, but the construction industry lags behind. Such systems require structured processes and an understanding of their principles by all parties. A strategic plan that will support organisational, cultural, process and technology change is required (Sear et al. 2008). The proposed client relationship management process model includes both strategic and operational aspects. Strategic processes allow the determination of client categories, the development of differentiation strategies, the transfer of benefits to the clients, the management of client related events, and the development of processes that allow CRM tools to be implemented. Strategic processes aim at the provision of a modus operandi for operational processes. Operational processes are related to the everyday implementation of the client based strategies and include the actual client grouping, the arrangement of client management teams, the identification of opportunities with clients, the negotiation and practising of contracts, the identification and management of events, the evaluation of client satisfaction and the measurement of performance. The depth of its implementation is dependent upon the organisation’s process and personnel maturity levels (Meng, Sun and Jones 2011, National Research Council Canada 2013). As proposed in previous research, the application of such a management system lead to improvements in profits, the identification of niche markets and the effective management of all clients (Dulaimi 2005). Such benefits though require commitment and continuous process improvement in order to align with client demands and, ultimately, improve client satisfaction rates (Sear et al. 2008). As the construction industry is highly competitive, the implementation of a CRM system can lead to new operating strategies such as whole lifecycle management of projects (Preece et al. 2015). Especially in times of low transaction frequencies such strategies may provide more effective management of existing clients and improve the identification rate of prospective clients. Current practices do not consider the maintenance of long-term relationships with clients and do not exploit the potential of the existing ‘after-sales’ project demand (Lönngren, Rosenkranz and Kolbe 2010).

New project development and commercialisation is a critical supply chain task for an organisation’s survival. Project development contains the detailed design, construction, operation, and demolition of a building. The design phase has the most significant impact of all phases on a building’s lifecycle (Yoo, Shin and Park 2015) and the coordination of involved parties is very important (Bouchlaghem, Kimmance and Anumba 2004). Different actors have different input levels to the project design phase (Brandon 2011) but there should be one that manages all the coordination efforts. In the proposed model, this actor is the contractor. Depending on the type of the contract, the contractor may either simply negotiate minor changes to the project with the client after consulting key suppliers or hold extensive negotiations with both sides of the supply chain. The involvement of both customers and suppliers positively influences relationship quality, knowledge transfer, and new product development performance (Sjoerdsma and van Weele 2015). The design process involves an information exchange between numerous designers (Lahdenperä and Tanhuanpää 2000) that through the coordination of a single person has to reach a final version that will minimise uncertainties related to the project (Winch 2001). Despite the importance of other actor involvement in the design phase, design is not always connected to the construction phase (Brandon 2011). This could be attributed to the fact that clients may employ designers to produce a final design before tendering or to the fact that contractors tend to pay more attention to client requirements than supplier requirements. Actors and their transactions are described by the term design chain; a subset of supply chain management processes. Despite the importance of the design phase of a project, there is no best practice tool that can be used to cover this phase (Bibby 2003). The DCOR model (APICS 2017B) is a benchmarking tool that covers design chain operations for the manufacturing industry, but some benchmarks such as the ‘perfect product design’ and ‘total design chain cost' metrics could be adapted to the construction industry. Tasks in project development are influenced by the actor interdependencies. These could be pooled, sequential, reciprocal or synchronic interdependencies based on the requirements of each task under study. To a bigger extent, since a group of tasks form a work package, these interdependencies exist between work packages and the actors they are assigned to. Work structuring not only affects coordination costs, but also task production costs (Tsao et al. 2004). The use of small work packages that have been identified at the smallest identifiable work level enable stable and continuous utilisation of work resources due to the flexibility they provide in cases of unpredicted constraints and events (Grau et al. 2014). This is rarely possible because the work structuring process is influenced by many considerations. Some of these considerations include considerations related to winning the tender (owner's requirements and budget constraints, requirements for use of local/disadvantaged/minority contractors, prequalification requirements, and licensing) and considerations related to construction performance (difficulty and complexity of the work packages, the quality of the subcontractors who will be attracted, interfaces and coordination requirements, and potential production problems) which are, in fact, conflicting considerations (Mitropoulos and Sanchez 2016). In a construction project, due to the supply chain fragmentation and the specialisation of each actor, each supplier may be involved in a limited amount of work packages. It is common practice during the design phase to agree upon most work package information but not to add the inherent uncertainties related to their execution (Boskers and AbouRizk 2005). This has a negative effect on the project during the construction phase and poses a source of claims. Most design phases are under a tight schedule and fast track practices are used (Bibby 2003), which leads the contractor or the designers to make hasty, but sloppy, decisions. In such cases, in order to reap the benefits of early supplier involvement, such as those described by Alleman et al. (2017), it would be practical to focus collaboration efforts on quantity significant work packages (Horner and Zakieh 1996) that carry the bulk of project costs. Each actor has his own interests in the way work packages are formed, such as conforming with local practices, availability of subcontractors, and avoiding second tier contractors in order to reduce bid costs caused by double mark-up (Mitropoulos and Sanchez 2016). A good solution that takes most parties' requirements and interests into consideration could be the application of modular construction, despite the concerns that are still related to this form of construction, such as owner's willingness to accept modularisation, early involvement of top management in the decision-making process, suitability of design for modularisation, construction schedule, cost, and site characteristics (Azhar, Lukkad and Ahmad 2013). The benefits of modularisation as described by Azhar et al. (2013) (time and cost savings, better quality control, reduced waste at site, reduced onsite labour, less reliance on foreign workers, better safety controls, higher productivity, design flexibility) can improve performance of project supply chains.

Project development processes are problematic. Excluding the fact they are understudied (Bouchlaghem, Kimmance and Anumba 2004), they are interdependent entities that require effective governance (Winch and Carr 2001). Currently, processes do not allow downstream information flow due to their high fragmentation (Anumba and Evbuomwan 1997). This means that it is common to have final designs that contain a large amount of flaws (Lakka and Nykänen 1992). These flaws lead to many types of waste at the construction phase (Juszczyk et al. 2014) that impact the project with increased costs (Lahdenperä and Tanhuanpää 2000). Sharing the development of the project across the supply chain allows a variety of external factors and transactional inefficiencies to arise, a problem that can be abated through the use of information technology (Yoo, Shin and Park 2015). BIM technologies allow the implementation of more collaborative strategies. Successful collaboration at the design phase can yield benefits to the entire project lifecycle (Shelbourn et al. 2007), whereas problematic collaboration can hurt the project from a very early stage (Primo and Amundson 2002). BIM underpins the exchange of information between clients, contractors and suppliers in a way that was not available in the past; real time monitoring and change management. Such technologies can allow practices such as the CM-GC to flourish.

The project development and commercialisation processes presented in this dissertation take into consideration the little related research available in order to provide a step by step process guide to the contractor since he is the actor that carries most risks related to this function. Strategic processes describe the steps to the generation of the required process guidelines for the execution of the operational processes. Operational processes are designed so as to take into consideration the type of project under study and its fit in the project portfolio, human resources needs, design and work package generation, and construct/subcontract considerations. The monitoring of these processes allows the identification of lagging tasks and their optimisation. It is a powerful tool to support project development that the literature lacks. This function mainly relates to the development of new projects. Other project phases such as construction are covered by other model functions, whereas phases such as the maintenance and operation stage are not examined since it is common practice to create separate legal entities to manage such tasks.

In today’s construction environment it is very hard to find one contractor that has the ability to self-perform all required tasks in a project. Continuously changing client demands, high costs for idle times, maintenance and personnel, legislation and volatile economic climate lead contractors to maintain core abilities and outsource/subcontract the rest. All these abilities are held by companies, mainly SMEs, which make up a large percentage of the industry. These companies provide their materials and/or services to main contractors. The majority of project related costs that incur to contractors are attributed to their suppliers (Nobbs 1993, Hinze and Tracey 1994, Vrijhoef and Koskela 2000, Ibn-Homaid 2002, Caldas, Torrent and Haas 2004, Karim, Marosszeky and Davis 2006, Mbachu 2008, Chiang 2009, Hartmann and Caerteling 2010, Yunna and Ping 2012, Safa et al. 2014, Mirawati, Othman and Risyawati 2015). The fact that these companies are involved in a project on credit provides contractors with an invaluable source of indirect financial resources (Lowe and Moroke 2010, Nicholas and Edwards 2003). In addition, the performance of suppliers can affect the overall project success (Ng and Skitmore 2014). Most contractors are aware of the importance of suppliers in the project but do not know how to make the most of their transactions (van Lith et al. 2015). There is a general lack of trust and negativity towards the concepts of supply chain management theory that hampers process and system alignment with supply chain partners, that can lead to improvements in project performance (Dainty, Briscoe and Millett 2001). The selection and management of appropriate suppliers and the respective relationships has become critical in contemporary projects (Dainty, Millett and Briscoe 2001, Karim, Marosszeky and Davis 2006, Hartmann and Caerteling 2010). Cooperation with suppliers can add value to the product/service, reduce any risk involved in the supply chain, reduce the costs associated with the supply chains as well as increase efficiencies (Pala et al. 2013). For example, there are many inefficiencies related to enquiries, tenders and quotations (Laryea 2009) that can be resolved through the development of closer relationships with suppliers. Currently, all parties pay way to much attention to their self-interests, thus making collaboration difficult (Akintan and Morledge 2013). Contractors tend to have some suppliers for each specialisation with which they collaborate often (Smith 1986), a sort of informal alliance (Vilasini et al. 2012). Interviews revealed that this true more often for small sized contractors that work on small scale projects rather than large contractors. This trend is even stronger in the residential building sub-industry (Eccles 1981). Given the long-term collaborations in this market, trusting relationships are easier to develop (Hartmann and Caerteling 2010). It is encouraging that most contractors have realised the need to develop closer and more collaborative relationships with their suppliers (Bemelmans, Voordijk and Vos 2012A). They have actually realised that the nature of long-term relationships enables specific value-adding ways of working (Bildsten 2014). Some of these value-adding activities include early supplier involvement in the project, information sharing and coordination of operations. The most intensive collaborations occur under partnerships or alliances. These management types can lead to competitive advantages that benefit involved organisations, project performance and client satisfaction. Increased client focus, in particular, requires that contractors mature along with their key suppliers in long-term relationships (van Lith et al. 2015).

Turning attention to the supplier relationship management process and closer collaboration with suppliers provides contractors with many benefits. In order to gain effectiveness in project planning and delivery, the contractor must integrate the expertise and knowledge of suppliers (Bemelmans et al. 2012). It is uncommon to find contractors that gather knowledge from their suppliers (Papadopoulos et al. 2016). Knowledge transfer can be improved through the active management of supplier relationships (Sjoerdsma and van Weele 2015). The mutual dependency between effectiveness and relationship management becomes obvious through the knowledge lens. Contractors have to become attractive partners in order for suppliers to be willing to cooperate with them (Carlsson 2008). A pool of suppliers that trust the contractor provides the contractor with an increased ability to activate market forces towards everyone's benefit (Hartmann and Caerteling 2010). In addition, closer long-term relationships with suppliers have proven to contribute towards process development/improvement (McGinnis and Vallopra 1999) and supplier knowledge can maximise cost and time advantages when developing new products, processes or services (Bemelmans et al. 2012). The adoption of closer relationships comes at a cost in both time and resources. This makes it imperative to identify the goals of such a relationship. Such goals include increase of speed, support, service, client satisfaction, logistical costs reduction, asset utilisation/cash flow improvement, improvement of cash flows speed, improvement of cross-enterprise relationships, improvement of decision-making, and improvement of communication (Bemelmans et al. 2012). In addition, selected suppliers must be able to adapt to the changes mandated by operating needs and contract change orders in the field (Benton and McHenry 2010).

Both general and construction focused literature have a good number of process models documented (Robinson et al. 1967, Webster and Wind 1972, De Boer, Labro and Morlacchi 2001, van Weele 2009, Cheng, Law, Bjornsson, Jones and R. D. Sriram 2010, Lambert and Schwieterman 2012, Pala et al. 2013, Bildsten and Manley 2015, van Lith et al. 2015). The problem associated with these models is that they mainly focus on the purchasing function and do not take into consideration all supplier relationship management processes. The holistic model described by Lambert and Schwieterman (2012) mainly focuses on the manufacturing industry, but provides the best approach to supplier relationship management available. The combination of details related to all the available models, along with an extensive literature review and documentation of best practices, provided a holistic supplier relationship management process model. The proposed supplier relationship management process model includes both strategic and operational aspects. Strategic processes allow the determination of supplier categories, the development of differentiation strategies, and the transfer of benefits to the clients. Strategic processes aim at the provision of a modus operandi for operational processes. Operational processes are related to the everyday implementation of the supplier based strategies and include the actual supplier grouping, the arrangement of supplier management teams, the identification of opportunities with suppliers, tendering and purchasing, the negotiation and practising of contracts, and the measurement of performance. Unlike other models in the literature, it attempts to cover all processes related with supplier relationship management and does not simply focus on a specific stage (e.g. tendering, purchasing). The models by Robinson et al. (1967), De Boer et al. (2001), Cheng et al. (2010), Pala et al. (2013), Bildsten and Manley (2015), and van Lith et al. (2015) fail to take a holistic view to supplier relationship management despite the fact that the ones by Pala et al. (2013) and van Lith et al. (2015) actually take into consideration the differentiation of strategic and operational processes. The model takes a multi-project approach that allows continuation of processes across many projects and in an extended time frame. As Vrijhoef et al. (2014) point out: "*Repetitive working must lead to strategic thinking, increased innovation and continuous improvement. This also enables to keep teams together for multiple projects, and to learn collectively as a result of continued work*". The model takes this into consideration when it promotes transfer of benefits to suppliers in order to build trusting long-term relationships. Suppliers must be selected on value added not just price, especially in today's sourcing environment (Benton and McHenry 2010). The most important aim for contractors should be the harmonisation of their processes with those of their suppliers in order to avoid wasting resources (Kawa and Koczkodaj 2015).

Performance management is undoubtedly gaining in importance in contemporary organisations. The construction industry should be no exception. There are plenty examples of performance measurement in construction supply chains (Nai-Hsin, Yung-Yu and Nang-Fei 2010, Pan, Lee and Chen 2011, Thunberg and Persson 2014, Wibowo and Sholeh 2015). As Oliveira et al. (2012) underline, the positive impact of a business analytics investment in supply chain management operations should not be taken for granted. Wagner et al. (2003) documented that SMEs have less influence on their external business environment due to their lack of resources compared to larger organisations. Organisations need a roadmap that leads them to a successful implementation of such initiatives. There is no universal strategy that can be implemented (Fredericks 2005), so it is important that all organisations identify their needs. In order to identify their needs, organisations must have an understanding of the maturity level of their processes. McCormack et al. (2009) showed that maturity importantly influences the business processes of a company or a supply chain and, consequently, its performance. A maturity assessment aims to establish a baseline for discussing the completeness and the quality of the set of processes executed in an organisation (Dumas et al. 2013). Improving supply chain performance has become a continuous process that requires an analytical performance measurement system (Cai et al. 2009). Construction companies are encouraged to start measuring the supply chain efficiency and make better comparisons with other companies in the construction industry

(Thunberg and Persson 2014). Without integrated enterprise systems, collecting and analysing enterprise-wide data for business intelligence is cumbersome, costly, time consuming, and error prone (Gulledge and Chavusholu 2008). The adoption of a good performance system could lead to enhanced risk management in projects (Chabchoub and Hachicha 2014). Finally, since it is quite possible that the use of business analytics does not bring immediate results, the performance should be measured with a time lag.

The processes in the KPI function are built on solid academic background and enriched with a market expert's opinion. It must be noted that there is no 'single truth' on how these processes must be executed, a comment that was provided in the specialised interview. This means that the processes described in this model are open to high levels of adjustments based on each practitioner's experience. Yet, as interviews with specialists in construction showed, there is a lack of such practices and their presentation is of great importance. The "Process maturity assessment" process aims at determining the maturity level of the organisation's processes while providing a framework of evaluation. Existing frameworks in the literature (Paulk et al. 1993, Coletta 2011, Oliveira, McCormack and Trkman 2012) can be used in order to classify the processes after discovery. Depending on the level of process maturity, different performance measures might be appropriate. The "Develop Key Performance Indicator framework" process describes the sequence of tasks that has to be followed in order to build the most appropriate performance measurement and evaluation framework for each project in particular and for core processes of the organisation. Metric frameworks such as SCOR and Balanced Scorecard have been used with positive effects in the construction literature (Nai-Hsin, Yung-Yu and Nang-Fei 2010, Pan, Lee and Chen 2011, Thunberg and Persson 2014, Wibowo and Sholeh 2015, Halman and Voordijk 2012, Abu-suleiman, Boardman and Priest 2004) either independently or complementarily. These frameworks provide tools for measurement but do not describe how their implementation should be conducted. The two processes are of a supportive nature and their combination can prove more effective compared to effects of each process on its own.

Demand in the construction industry is particular. It is affected by many factors, but the main problem is that companies at the contractor level do not attempt to forecast demand on their own and rather rely on forecasts made at a governmental level. Demand management should be approached proactively in an attempt to collect new project ideas that represent a strategic direction (Romano, Grimaldi and Colasuonno 2016). Construction contractors may handle a portfolio of diverse projects, and demand for each type of project affects the portfolio. In general, demand management in construction is lagging compared to the manufacturing industry. Aside from a few demand forecasting works in the literature (Akintoye and Skitmore 1994, Fan, Thomas Ng and Wong 2007, Hua 1996, Hua and Pin 2000, Tan et al. 2015, Wong, Chan and Chiang 2005, Fan, Ng and Wong 2010, Jiang and Liu 2014, Vidalakis, Tookey and Sommerville 2011) which focus on housing, as predicted by Winch (2003), there is no clear methodology for demand management such as the one presented in this dissertation. The majority of demand forecast publications originate from Asia, more specifically Hong Kong and Singapore, and refer to the 1997 economic meltdown in the region. This indicates that there has not been enough analysis of the effects of the 2008 worldwide economic meltdown on larger markets such as the U.S.A. or the E.U. Demand for construction products differs in relation to the type of product in need (houses, manufacturing plants, infrastructure, etc.) and the region under study. National forecasts performed by government authorities cannot provide contractors with a clear view of demand

and opportunities/risks in their local markets. In cases of developing markets, the fluctuation due to changes in local economic conditions and demand may not be too difficult to predict as they follow a pattern, but as markets mature the pattern becomes unclear and it is difficult to forecast the extent of the effects of this change (Fan, Ng and Wong 2010). Government forecasts are nonetheless useful tools that predict construction demand in a medium term, thus allowing policy-makers and industry practitioners to strategize against fluctuations (Fan, Thomas Ng and Wong 2007). Forecasts at the organisational level are even less common. This hinders the contractor's ability to formulate bidding strategies that will increase their chances in the tendering process (Bee-Hua 1999). Demand forecasts can affect the number, price level, and success level of tender bids (Li, Ogier and Cullen 2006). Additionally, demand forecasts can provide insight to the demand for manpower and, if demand is to decline, contractors may choose to train their staff for new types of projects instead of hiring new staff.

There are many factors that may be taken into account during the forecasting process depending on the type of project under question (Fan, Thomas Ng and Wong 2007, Hua 1996, GOH 1998, Grenadier 1995, Jiang and Liu 2014). Accurate demand forecasts allow inventory positioning that leads to more efficient projects. Contractors should select between strategies that decrease variability or increase flexibility in their supply chain, but keep in mind that their choices have to be cost effective and aim at key partners that participate in many of the projects in their portfolio. Demand fluctuations tend to look larger the further back the supply chain an organisation is placed. In manufacturing this phenomenon is called the 'bullwhip effect' and its main cause is the lack of effective communication between supply chain partners (Bhattacharya and Bandyopadhyay 2010). Construction contractors behave in similar ways by delaying the communication of demand information to their suppliers in order to minimise risk related to changes (van Donselaar, Rock Kopczak and Wouters 2001). Synchronisation of supply chain partners is an important measure in order to improve management of the bullwhip effect. Manufacturing companies use techniques such as VMI (Vendor Managed Inventory) or CPFR (Collaborative Planning Forecasting and Replenishment) to manage their inventory flows, but these techniques could not have any impact at the construction contractor's level. Only in the case of housing is demand volume high enough to allow such approaches to be economically viable (Winch 2003). There is no research on the bullwhip effect in construction. How does the bullwhip effect manifest in the construction industry? Is it caused by large public projects? What are the effects of large projects on the management of the bullwhip effect on construction suppliers from the manufacturing industry? Is reducing variability up to the contractor or is increasing flexibility in construction supply chains more feasible? How do small profit margins affect such decisions? Such questions provide areas of potential study regarding demand management in construction supply chain management.

There are trends in the literature proposing that classic project management tools such as CPM/PERT are no longer effective in work package management (Huang, Ibbs and Yamazaki 1992, Koskela and Howell 2002). One has to keep in mind that, in production, effectiveness refers to maximising value of the output whereas efficiency refers to minimising or eliminating non value-adding items (Horman and Kenley 1996). Poor flow of work packages contributes to labour inefficiencies (Thomas et al. 2003) and additional costs (Formoso and Isatto 2009, Tsao et al. 2004). Planning and monitoring of work flow requires the definition of each task that comprises a work package (Grau et al. 2014). A problem is posed by the fact that organisations in the industry lack good project status reporting systems (Romano, Grimaldi and Colasuonno 2016). Work flow has to consider the interdependencies between work packages as described by (Crowston 1991). Coordination of these interdependencies is critical and so is the resolution of problems that occur (Mitropoulos and Sanchez 2016) in order to avoid the creation informal work packages as much as possible (Fireman, Formoso and Isatto 2013). Despite each projects' uniqueness, construction processes at all levels are, mostly, the same and repeated from project to project (Wamelink, Stoffele and Aalst 2002). This means a significant number of uncertainties are shared among projects that may not share other commonalities. These uncertainties make planning and execution of work packages a cumbersome task. Planning, and its subsequent processes, bears great importance on the success of a project (Zwikael 2009). Planning provides all the necessary information for the successful execution of the work package (Meredith and Mantel 2009). During planning, a number of constraints must be taken into consideration before the work package is released to execution (Choo et al. 1999). Execution of work packages presupposes levelling of resources (Binninger et al. 2016) and is performed in slots named Takt units. The nature of Takt plans allows the identification of problems when work packages fail to complete on time (Vatne and Drevland 2016). To support the planning and execution monitoring function, Li et al. (2006) propose the use of database management systems (DBMSs). The adoption and implementation of such systems may present additional costs since users may present a long learning curve in addition to the need to provide access to subcontractors. However, successful Takt planning requires the collaboration with subcontractors (Vatne and Drevland 2016). The literature is abundant with works documenting problems in work package management, such as Choo et al. (1999), Ponticelli et al. (2015), Gardner (2006), Mitropoulos and Sanchez (2016), Binninger et al. (2016), Leão et al. (2014), Draper and Martinez (2002), and Vrijhoef and Koskela (2000). Koskela and Howell (2002) support that the current practice of project management in construction is obsolete and propose a take at the production theory would be beneficial. It is through this lens that the work package management process model was built. The proposed function focuses on work package management planning and the information exchange along the supply chain during work package execution. Information exchange is a rudimentary part of supply chain management as seen in the adopted definition of supply chain management in this dissertation. Collaboration, communication and alignment between the involved parties are of great importance. The general contractor plays the role of the information hub collecting, analysing and distributing information on work packages. It has been proven by Lee et al. (2016) that effective work package management can have positive effects on modular production as well. The advent of the advanced work packaging methodology provides a management basis for collaboration between involved parties from a very early stage in work package management development. The Work Package Management process model presented focusses on the actual management of the work packages during the project execution phase, leaving involvement of other parties in the early planning stages at the Project Development and Commercialisation function. It does not contradict the proven results of advanced work packaging adoption; it merely makes the differentiation between the master planning and the lookahead and weekly planning stages clearer. Additionally, the Work Package Management function takes merit of the quality control function and the effects, such as those presented by Leão et al. (2014), its' lack has on project execution.

Construction logistics are a core subgroup of construction supply chain processes that relate to the management of resources on the worksite and the completion of the end product. Logistics operations include the consumption of input, management of output and the related planning activities. Current logistics practices have large lead times that do not allow for value creation during the remaining process execution time (Arbulu et al. 2002). Bad logistics cause unnecessary costs, contribute to the poor image of the construction industry, burden quality, increase project time, and add risks to health and safety (Rogers 2005). Bad logistics are magnified by the involvement of subcontractors that impact the nature of flows in the construction supply chain (Sacks 2016). Regional subcontractors mean that contractors should plan ahead in collaboration with subcontractors if they want work to flow as scheduled and avoid shortages of service due to subcontractor overworking. Subcontractors, though, are not the only party causing problems in construction logistics. Contractors lack the mechanisms to calculate potential logistics costs, mainly due to that they are unaware of the requirements of handling their material orders (Ekeskär and Rudberg 2016). It is a daunting task to manage logistics in an ever-changing environment such as the worksite. The nature of the worksite causes uncertainty to the managers and in turn, their uncertainty is transferred to suppliers causing many logistical problems to their inventory policy and, in the end, quality issues to the project (Vidalakis, Tookey and Sommerville 2011). Additionally, poor scheduling on the contractors' side makes handling worksite logistics even harder by causing shortages in materials or shortages in space to store early deliveries (Brockmann 2012). Storage on site can last for long periods of time before products are moved to parts of the site for consumption (Rogers 2005). On the one hand, in cases of spacious worksites, pre-planned storage areas can be situated either centrally in the goods receipt area or in construction sectors (Ebel and Clausen 2007). On the other hand, in cases of worksites facing space scarcity, other methods may be more appropriate. Off-site production is presented as a favourable solution that takes advantage of manufacturing advantages (Gann 1996). Despite the cost cuts and the quality increase promised by off-site production, the level of modularity required for the appearance of such benefits restricts the flexibility and innovation of design. Additionally, the construction market has not reached a level of mature demand in most countries, thus not allowing for manufacturing off-site to be a viable choice. Another method of improving construction logistics is through the application of lean tools. Lean management can not only lead to better coordination of construction logistics, but also reduce the large amount of waste produced in the construction site (Howell and Ballard 1998). Lean construction adopts a management toolset that has proved largely successful in the manufacturing industry, provided some assumptions to allow them to fit the industry characteristics. Despite the apparent benefits of lean construction, the adoption of it has been slow and has even been met with criticism by practitioners and academics. Lean construction requires the acceptance of the practice by other supply chain parties, especially ones upstream, since it disrupts their usual practices (Ebel and Clausen 2007). Work crews share their time between multiple projects and have to be persuaded about the benefits of the change in their practice. Subcontractors must be given a direct interest in productivity outcomes, but contractors cannot provide such motivation since they lack interest in productivity outcomes due to their notion of buying products at fixed prices (Sacks 2016). Another way to improve logistics in construction could be the use of third party logistics (3PL) (Ekeskär and Rudberg 2016). 3PL companies provide logistics services between two companies and perform all relative activities (Mentzer et al. 2001). This could be beneficial for contractors since there is a lack of understanding of the constraints of the supply chain on their own and their subcontractors' behalf (Rogers 2005). The use of 3PL can reduce the effects of demand variability on lead times and system costs (Vidalakis, Tookey and Sommerville 2013). Finally, BIM software could, in combination with the previous methods or not, provide a solution to many problems of the worksite and the related logistics. There are two main problems impeding BIM adoption in the industry. The first is that the effective use of BIM requires the exchange of information between parties that requires a higher level of trust than that existing in the industry. Second, the costs of acquiring such software are prohibitive for the majority of the construction industry given the large percentage of SMEs. Logistics management seems like a hard puzzle to solve and manufacturing characteristics seem distant to the construction industry, but benefits could be gained nonetheless by examination of manufacturing sectors with practices close to construction (Winch 2003), for example the aerospace industry studied by Voordijk and Vrijhoef in 2003.

The construction flow management function is comprised of three strategic and four operational processes that make use of many best practices in the literature. Lean practices, BIM and manufacturing practices are incorporated to the processes in an attempt to allow for their best utilisation by construction managers. Strategic processes extend outside the boundaries of a specific project into the entire project portfolio. Given the locality of the construction industry, the study of the logistics needs of more than one project provides support to the decision-makers on investments regarding their logistics practices (e.g. 3PL, inventory). Operational processes support the day to day organisation of logistics onsite and the scheduling of deliveries and work crews according to the needs of the project while taking advantage of any possible time buffers.

Claims are mainly a result of the human factor influencing the construction process. They have a disruptive effect on projects and are very unpleasant for the implicated parties (Ho and Liu 2004). Even though they may start against a single party, they tend to affect more than one parties (Chester and Hendrickson 2005) and spread along the projects' supply chain. Although many claims stem from unforeseen events, in many cases it is the ambition of specific parties to take advantage of these events in order to enhance their profits (He and Chen 2010, Yang and Xu 2011, Zhou and Tan 2012). This opportunistic behaviour is partly to blame for the adversarial environment in construction. This adversarial environment severely impacts a projects supply chain (Matthews et al. 2000). Competition between companies is transforming to competition between supply chains in almost every industry. The construction industry should not trail behind in this transition and this requires a lot of effort from companies to combat its inefficiencies. Contractors still follow tactics of global claims; they do not plan ahead and expect that through negotiation with clients their inefficiencies will be hidden. This burdens the entire supply chain with adversarial relationships. The temporary nature of construction supply chains does not allow for these relationships to be treated and future cooperation is rife with prejudice. Adopting a holistic strategy for the entire supply chain should improve efficiency of contractors, improve the relationships between supply chain actors and hopefully lead to a less stressful claims process. A good strategy would be to include claims management processes in contracts in order to standardise this function along the supply chain of the project.

Process models are becoming more and more popular in the literature and researchers and managers today have a broad selection of methods and tools to assist them in their effort to record company processes. Process models existing in the literature have specific characteristics. Moura and Teixeira (2007) and Kululanga et al. (2001) present a rather simplified process model for claims management with the only difference between the models being that the latter authors include a total quality management (TQM) related task in order to highlight the importance of improving the claims management process in each company. These processes, however simplistic, provided the backbone to the model presented in this paper. Banwo et al. (2015) added the time parameter to the claims process through the phases they introduced. Additionally, their model includes checks between phases and is the first to introduce invalid claims to the process. This is adopted in the proposed model with the belief that this feature helps to reduce the load of processing this type of claims from the relative department in a company. Abdul-Malak et al. (2002) describe a process for claims management that is very factual and analytical. It differs to the previous models in another aspect to, it is IT (information technology) oriented. The processes they described are a guideline to handling the software they developed for claims management. This orientation is crucial in order to identify low and high level processes, find where gateways are positioned in the processes and detail the company processes related to claims. The processes described in this paper provide the reader with a holistic model for claims management. In addition to claims management, a contract cancellation management process is proposed. Contract cancellations may lead to claims or derive from unresolved claims. Either way, their impact on the project supply chain is too large to ignore. These processes, based on the literature, where enhanced with information that was not previously documented and provide a better overview of industry practices. Furthermore, a performance measurement process is proposed, that builds on the identification, by Kululanga et al. (2001), of a need for performance measurement and improvement of intra-organisational processes and their interface with the company's environment. Users may select any measuring method they feel is best suited to their needs. It is proposed that some of the performance indicators should be common, or at least shared, with select supply chain parties in order to allow for better cooperation and assist the uniform development of future relationships with these parties. The reference model builds on the work of the earlier process models but takes a whole new perspective to claims management. It views claims from a supply chain standpoint. These transactions will ensure that key processes in the company work in harmony, thus enhancing efficiency. What was interesting about the interviews, was that both interviewees, despite working in different counties, agreed that the processes described in the reference model applied to both markets. Before the application of such a model along the entire supply chain of a project though, the company has to make sure it has the managerial capacity to implement it successfully. Starting by intra-company processes, it should realise its own level of readiness. Lockamy III and McCormack (2004) present a thorough process discovery guide that will support the adoption of process reference models.

The levels of interrelationships between functions may differ in each contractor organisation, thus a quantitative approach was avoided. The qualitative approach describing the levels of interrelationships can provide adopting organisations with a picture of what to expect upon adoption of the reference model. In addition, this should make clear that there may be a gradual adoption of the model but that a partial adoption of the model may not yield the expected results. The level of interrelationships between the "Determine supply chain management strategies" and "Develop key performance indicator framework" shows the importance of selecting specific strategies and then using measurement tools to identify their level of success. The level of interrelationships related to the "Client relationship management" and "Supplier relationship management" functions show the importance of client and supplier relationships in a supply chain environment. “Demand management” proves to be a critical function for the survival of the organisation as a whole and for the success of any supply chain management initiative. The interrelationships between the “Project development and commercialisation” function and the “Work package management” and “Construction flow management” functions prove how important the design phase is for the projects successful completion. Client and key supplier involvement in the design phase is a prerequisite for good planning and minimising changes or errors during the construction phase. Good project management and work site organisation skills prove to be critical for cost and operations efficiency. Finally, “Claims management” is a function that can make or break profits for the contractor, especially in highly competitive and opportunistic environments. The contractor’s behaviour during the claims process can really harm or really lift future work prospects with other supply chain parties. In addition, change claims, if not resolved in time, can throw project management off tracks. As it can be seen, certain functions hold some priority over others, when strategizing, but in no case should any of the functions in this model be ignored if results are to be seen in long-term.

Process reference models offer their users a common roadmap for their process management attempts without dictating how each low level task should be executed or how each detail should be handled. Desired results are achieved more efficiently when activities and related resources are managed as a process; identification, understanding and management of a system of interrelated processes for a given objective are conducted; and continuous improvement of the organisation's overall performance is forwarded (Coletta 2011). The benefits of such models include the flexibility to adapt to low level processes and existing needs and systems in each company and the provision of a common ground for navigating between inter-company processes. The process reference model presented here has the advantage that it retains a certain level of abstraction, thus allowing it to bind well with any existing ERP or other IT solutions in any construction company or provide a framework for the adoption of such systems, as proposed by Pajk, Indihar-Štemberger and Kovačič (2011).

5.2. Analysis of interviews

Validation of the reference model was required. The available validation methods included simulation, case studies and interviews. Case studies were not selected as data collected would have been confined to a single source. This would harm the generalisability of the reference model. Simulation, despite the fact that the reference model built is capable of simulating different data sets, was deemed unfitting due to the large amount of data required and its unavailability. The selected validation method was that of semi-structured interviews. Interviews allowed the use of multiple sources of information that lead to better validation of processes and tasks that were reviewed by multiple experts. In addition, interviews provided more chances to identify missing processes and tasks in the literature and the similar input from multiple sources of information confers to the generalisability of the reference model. The high level of experience among interviewees means that information collected was of better quality. Furthermore, the analysis of the interviews confirmed some of the industry’s strengths and weaknesses recorded in the literature and identified opportunities for improvement based on literature best practices. Differences and similarities between supply chain practices of SMEs and large contractors were identified and analysed during the validation process.

The interviews conducted provided some best practices that were mentioned during the first edition of the process reference model. In addition, the interviews presented some interesting findings that either corroborate the literature or provide new data for the analysis of the industry. This data is best made understandable when comparing practises followed by large contractors and practices followed by SME contractors. The vast extent of the reference model describes practices followed by both types of contractors and this proves its generic nature that fits most contractors in the construction industry. A comparison of interview results provided by SME and large contractors provides some insight to the differences between contractors in the industry. Differences per function are described in the following paragraphs.

Regarding the ‘Determine supply chain management strategies’ function: Interviews with SME contractors revealed that they do not follow any specific supply chain strategy. This is understandable as they exist in an extremely volatile environment that does not allow them to formulate a clear general strategy with which a supply chain strategy can be connected. Survival is the main focus and they switch activity focus between project types as the market changes. This shows high adaptability and flexibility and this can be connected to the fact that there is usually a single decision maker with immense market experience leading the company. In contrast, large contractors have specific strategies that are dictated by the high management levels of the company. Despite the fact that there is a robust strategy, interviews did not come up with results regarding specific supply chain strategies. Survival is a different concept for large contractors that have the ability to select new markets to enter in order to maintain their activity level, if not to expand it.

Regarding the ‘Client relationship management’ function: Interviews with SME contractors showed that in some cases contractors select their clients based on a profile of their company built over the years. This means that there are cases where clients are rejected, with not much consideration of the scale of the project, in order to maintain the desired profile. A benefit for SME contractors is that they get to develop a personal relationship with the client, especially in the private housing industry, and this allows for interpersonal trust to be built. This means that their clients have more chances of becoming repetitive clients that will contact the contractor for projects of different scale in the future. In the case of large contractors, they may have repetitive clients but this can either be attributed to trust built between organisations (not people) in past projects or cases of multi-project contracts spanning a fixed time frame. Interpersonal trust is harder to build as client management activities may be handled by different personnel than the personnel actually responsible for the work execution. Common practice between both types of contractors is the generic differentiation of clients into public and private. As seen in the literature, the differentiation made by contractors can be more detailed and the benefits of using such differentiations can be many. Another common practice is the maintenance of a client record by all contractors, although the detail of the record may differ. In both cases, contracts are negotiated to some extent. Public clients do not leave much room for negotiation of the contract but usually provide a short period for clarifications and amendments. The difference lies in the fact that negotiations with private clients are, in most cases, conducted verbally by SME contractors, but large contractors maintain written documents for the negotiation. In addition, when legislation does not dictate otherwise, large contractors use negotiation protocols such as FIDIC for their contract management processes.

Regarding the 'Project development and commercialisation' function: Interviews with SME contractors showed that they evaluate projects based on their type. They differentiate project types based on their nature of work; new housing or renovations for private clients and public housing, plumbing, mechanical engineering works, or roadwork for public clients. In addition, they always consider project surroundings and the limitations they pose to the project. SME contractors can only carry out public projects up to a specific size due to legislation. Large contractors are still bound by legislation regarding public projects but their size and past gives them access to a larger project variety. Large contractors select their projects based on their experience with similar projects and the country the project is placed. In addition, they consider the legislation, tax and tariff systems and the general financial climate when considering international projects. It becomes apparent that the scale of projects that SME contractors and large contractors evaluate differs greatly. In addition, SME contractors consider the choice of investing in self-financed and self-developed projects when the financial climate allows it and invest in such projects with the hope of finding a profitable client along the way. This is particularly common in the private housing industry.

Regarding the 'Supplier relationship management' function: Interviews with SME contractors revealed that they maintain a pool of 3-4 suppliers for each type of work and then select a supplier for a specific project based on criteria such as price, specifications, work quality, and technical know-how. There are cases where they may select a new supplier based on a client recommendation. It is common for SME contractor to maintain long-term tight and personal relationships built on trust with specific suppliers. Large contractors may have preferred suppliers but the particularities of the projects they are involved in require that the main criteria for supplier selection are price and client specifications. Suppliers carry different weight on each project and this means that their intra-organisational categorisation may change according to each project. This is true mainly for large contractors, but can be practiced by SME contractors to. A field where practices differ is the recording of supplier performance. On one hand, SME contractors do not keep official records of past supplier performance but in case trust is breached they discontinue collaboration in future projects. On the other hand, large contractors maintain official records of supplier performance and they may use these records in order to evaluate suppliers in new projects. SME contractors sign official supplier contracts when legislation requires it or when the work volume dictates it. Large contractors always sign contracts with their suppliers and in most cases use protocols such as FIDIC to manage these contracts. Finally, SME contractors reported instances of client interference in the negotiations with suppliers, whereas large contractors did not as long as the supplier met all specifications set by the client. Furthermore, SME contractors revealed that in some public projects they need permission from the client to subcontract a specific type of work.

Regarding the 'Develop key performance indicator framework' function: Interviews with SME contractors revealed that they do not assess their process maturity or develop and use key performance indicators in their activities. This can be attributed to the lack of managerial knowledge to do so or to the unaffordably high cost of developing such a system. The information about such practices by large contractors is messier. In one instance, a large contractor reported the adoption of ISO prototyping systems for specific processes. The adoption of these systems requires an assessment of existing processes (Harmon 2016), a critical task of process maturity assessment. In addition, the contractor reported that processes were updated when inefficiencies were identified. The specific contractor also mentioned the use of a self-developed KPI framework or a client imposed KPI framework to monitor specific activities. In another instance, a large contractor reported the adoption of certain ISO prototyping systems but reported that KPIs were not used in the company. In the last case, data would be provided to claim consultants in order to identify KPIs for claim management purposes. The lack of adoption of process maturity assessment and performance measurement practices by the majority of contractors (SMEs make for the vast majority of companies in the industry as seen in previous chapters) in the construction industry means that they cannot yet reap the benefits associated with these practices such as improved innovation, cost and profit improvements, and better collaboration.

Regarding the ‘Demand management’ function: Interviews with SME contractors revealed that they identify the following sources of demand: social media, mouth-to-mouth, reputation, acquaintances and “collateral” projects (projects that occur by visitors to existing work sites) for private clients and internet sources, government agencies and National Strategic Reference Frameworks for public clients. Large enterprises identified the same sources for public clients but reported the following sources for private clients: financiers, repetitive clients, backlog projection, entry in new markets and invitations to international project tenders. The difference in demand sources is clearly related to company size and activities. Despite the fact that both types of contractors identified demand sources, none of them performed demand forecasts as they believed them to be unreliable. This contradicts the findings in the literature that found demand forecasts for specific types of projects to be beneficial. Furthermore, an interesting find is that contractors find it easier to increase flexibility than to reduce variability. This contrasts manufacturing companies that associate increased flexibility with higher costs than variability reduction (Croxton et al. 2002). The explanation could lie in the traditional practice of subcontracting in the industry, a practice that according to Winch (2003) inspired outsourcing in the manufacturing industry.

Regarding the ‘Work package management’ function: Interviews with large contractors revealed that they consider five main groups of work packages in a project, namely enabling works, earthworks, roadworks, major structure, and furniture. SME contractors considered enabling works, earthworks and major structure as the main groups of work packages. SME contractors reported that they try to take advantage of economies of scale and when managing similar work packages across multiple projects. Large contractors reported that economies of scale where created within the work packages of a single project due to project size. The way both types of contractors manage their documents is similar, although some differences identified were the following: 1) the number of produced documents for large contractors requires the creation of a document registry whereas SME contractors use a simple filing system, and 2) large contractors keep timesheets as a separate document from the work site diary whereas SME contractors log work times in the work site diary. Furthermore, large contractors are the only to mention the use of a preliminary document registry. Regarding the actual management of the work package execution, large contractors employ superintendents on the work site, whereas SME contractors do so only when required by the client or when there is a lack of specific know-how for an activity. Another difference in work package management is that SME contractors perform sign-offs once (upon project completion) whereas the size or client requirements of large contractor projects necessitate multiple sign-offs (at major milestones). A common characteristic of both large and SME contractor work package management is that they do not use the EVA method to monitor project progress. Large contractors are aware of it, but prefer to monitor progress through project management software such as Primavera or MS Project, whereas SME contractors are not aware of it and use a combination of experience in project management and invoices to monitor progress. Finally, the two types of contractors reported different types of problems related to the work package management function. SME contractors reported problems related to finance, time, supply chain constraints and reworks that affect their work package management processes. Large contractors reported problems related to poor monitoring, over-optimistic planning, poor resourcing information, addition of new work packages and omission of work packages from the project plan as major disruptions to their work package management functions. The differences in problems can be attributed to the scale of projects and to the size of clients for each company.

Regarding the 'Construction flow management' function: Interviews with SME contractors reveal that, although they are not aware of the Line-of-Balance technique, they practice it in their projects depending on the scale of the project. This can be attributed to the fact that project management experience in SME contractors is concentrated in a very limited number of personnel. Interviews with large contractors indicated that they may be aware of the technique but do not find it applicable to their projects. This can be possible when clients tender each work package of a project separately in an attempt to save costs (mainly practiced by governments of developing countries). Interviews revealed that all contractors attempt to resolve rework problems on-site at the time of their creation, and that only in extreme cases do they have to plan them in their programmes. Despite the fact that space is considered a big problem in the literature, SME contractors seem to be the ones facing the biggest implications. In most of their projects space management poses a problem that increases costs and interviews revealed that their relationship with the client is the most important determinant for this cost's allocation. Large contractors usually do not have such severe problems with space shortage but they report that extra planning efforts are put into the analysis of site conditions, safety, points of entry/exit to the work site, cost analysis of site logistics, need for dedicated logistics teams, and risks associated with on-site storage. The use of distribution centres is appealing to SME contractors but the costs associated with them are a major obstacle for their creation. Large contractors may use distribution centres for equipment and large materials but place them on site when the project scale allows it.

Regarding the 'Claims management' function: Interviews with SME contractors revealed that claims only occur from clients of public projects but are usually resolved between the two parties and only rarely need arbitration. SME contractors reported that they do not follow specific claims management processes. Large contractors have dedicated legal departments for the resolution of claims in their projects and reported that only in extreme cases do claims end in litigation.

Regarding the use of information technology: Interviews with SME contractors revealed that they use computer design tools to produce their designs, simple spreadsheet software such as MS Excel to manage invoices and file sharing tools such as Dropbox and OneDrive to share project documents to involved parties. In addition, they use cameras to create time-lapses of the worksite for management and security reasons. In contrast, large contractors use more specialised software tools such as MS Project and Primavera for project management, SAP tools for cost management, and specialised monitoring technology such as drones and BIM-based tools. Large contractors reported that they allow access to specific software applications to key suppliers. Interviews indicate that BIM adoption is still in its first steps in Greek contractor organisations. Interviewees underline that use of BIM tools depends on the scale of a specific project and only contributes to the smoothening of interfaces between actors. It was reported that the basic inhibitor to the use of such systems lies with organisational culture. Interviewees claimed that the fact that lower level staff is more IT literate than senior staff can cause conflicts and reduces the effectiveness of such tools because of the fact that people with the technical know-how to use them have limited log-in, modifying, managing, and updating rights compared to more senior staff that have less competence in their use.

6. Conclusions and further research

The construction industry is one of the oldest industries around. Despite this fact it has been slow to adapt to the requirements of modern clients. The main reasons are lack of innovation and adherence to traditional procurement practices that create adversarial relationships between parties implicated in construction projects. In the past twenty years there have been many attempts to resolve the problems faced by the industry. Initially, governments were the ones to pave the way; currently academics have greatly expanded the field. The focus of the research is on construction supply chain management and the analysis of how relationships, firms and projects interact under this lens. The need for a tool that can translate the findings of the literature for implementation by practitioners was covered in this dissertation. The process reference model developed considers all supply chain management aspects in construction projects and offers a visualised methodology that can be readily adopted by construction companies seeking to study their supply chain practices. Nine functions of a construction supply chain cover all these aspects in a way that is useful for both academics and practitioners.

The construction industry has its particularities even in the determination of supply chain management strategies. They are highly affected by the uniqueness of projects, the uniqueness of supply chain networks that are involved in each project, and the contractor's abilities to collaborate with supply chain parties. The selection of a specific strategy depends on volatile market conditions and requires a certain level of flexibility. There are tools that support the construction process but there is a need to integrate them in order to support all collaboration types. Collaboration in a project is based on processes that allow interactions between the involved parties. It is important to reach an understanding of each party's processes and then, depending on the common interests of both parties, attempt to integrate them in order to reach to the successful implementation of the project. There are different levels of collaboration ranging from one off transactions to partnering agreements. The transition from the prior to the latter type of relationship is through a rocky road, but the returns in benefits are, in carefully selected occasions, definitely worth the effort. Construction supply chain management strategies have to take a holistic approach including both relationships with other parties and management of day to day construction site activities. At this level it is impossible to foresee all potential problems, but a good strategy provides the guidelines to overcome any obstacles.

Clients are the life source of any organisation. Construction organisations, usually, do not realise the potential offered by the management of their clients in an effective and efficient way. Despite the fact they pay more attention to their clients than their suppliers, they are unable to reap any substantial benefits. Clients are complex in their nature, behaviour and requirements, and just as there are no two identical projects, clients are very diverse. Client relationship management in construction rarely escapes the traditional contract based guidelines and factors such as trust, client satisfaction and fulfilment of client needs are not examined. The application of a client relationship management system, combined with the required organisational, cultural, process and behavioural changes, can provide contractors with many benefits. Benefits such as improved profits, client satisfaction and trust building can lead to long-term collaborations with clients that allow businesses to survive and grow. One-off projects provide temporary profits, but a structured client relationship management system has many more benefits to offer. Contractors have to leave practices of the past behind and move forward with the adoption of systems that have proved their effectiveness in other industries over many decades.

Project development and commercialisation is a very important management function that directly affects the survival of a construction company. Despite the importance of this function, there has been little relative research conducted. Researchers mainly focus on the design phase and do not extend their research to other development issues. The model presented takes a holistic view to the project development issues and best practices. It includes all the processes related to the examination of new project suitability to the portfolio to the analysis of personnel needs, design and outsourcing decisions. Is there a cause for the lack of related literature and models? Could this be attributed to the one-off nature of construction projects? Despite the one-off nature of projects, project development is a function that is executed very often in construction, even if it does not always yield results by winning every tender. The improvement of the processes related to this function could only offer benefits to the contractor, especially if key suppliers are involved in the function from a very early stage.

Contractors cannot possibly have all the skills and resources required to complete a project. This is why they turn to material suppliers, subcontractors and specialists in order to complete the tasks the client has requested. It is important to understand that suppliers play a key role in the successful completion of a project. Not only can suppliers deliver lower prices and broader profit margins, under the right circumstances they can increase the added value of a project. Thus more attention must be paid to the management of supplier relationships. The application of a supplier relationship management system, combined with the required organisational, cultural, process and behavioural changes, can provide contractors with many benefits. Benefits such as improved profits, long-term relationships, increased innovation, knowledge and expertise sharing, and trust building can provide contractors with a powerful market position. This requires taking the focus off temporary profit seeking and identifying the suppliers that are willing to increase collaboration and share benefits. It is important that contractors leave sterile practices of the past behind and move forward with the adoption of systems that have proved their effectiveness in other industries over many decades.

Performance management and business analytics have become critical for an organisation’s success in the contemporary market environment. Construction is a highly competitive market, but the domination of SMEs does not allow for practices like these to become the norm. Implementing strategic performance management and business analytics schemes requires the dedication of resources that are most likely already lacking. A process maturity assessment process model and a KPI framework development process model that interact in order to allow organisations to identify areas of improvement from a process perspective are described. These process models can be used in order to assist the adoption of existing tools in the literature such as SCOR, Balanced Scorecard and SPICE.

Demand for construction projects is affected by many diverse factors that need to be taken into account when performing forecasts. The fact that different factors have different weights on the demand for different project types means that a portfolio of demand forecasts should be created. Demand management is a field that lacks attention in construction literature, despite the large portion of attention it has received in other industries. Research is limited to application of forecast methods aiming to either test applicability of statistical tools or forecast demand at an industry level. A function such as the one presented in this dissertation is needed and its application can provide construction contractors with benefits such as clarity of future demand, cost reduction and plans to manage disruptive events.

Work package management has been mainly studied through the project management lens. The production lens has been clearly used less but provides a good amount of opportunities for improvement. The contractor plays the role of an information hub in the proposed model, but coordination, collaboration and alignment between project parties is required. The function described focuses on the strategic analysis of requirements, supply chain capacity, planning and risk management and the operational aspects of mid-term planning, execution and monitoring of work. Quality control and coordination are two main focus points of the model.

Construction logistics are part of the broader construction supply chain concept and they hold an important role in the successful implementation of a project. Their complexity is unanimously held as a contributing factor to the failure of meeting project goals. Construction logistics can benefit from better scheduling, use of innovative software and applying tools and methods from the manufacturing industry. The function described attempts to collect best practices, tools and methodologies recorded in the literature and group them according to the time horizon of their practice. This resulted in seven processes, three strategic and four operational that extend from construction planning to execution and monitoring and their relative strategies. There is no similar process model available in the literature to build on and this constitutes this modelling effort innovative.

Claims are highly affected by human behaviour. Omissions and errors in contracts or projects may become the playground for managers with opportunistic behaviour. This behaviour harms the relationships between the two actors, disrupts the supply chain of the project and, in the end prolongs the image of construction as a problematic industry. Claims will always accompany construction projects, but the way they are handled will make the difference. A win-win culture must be promoted and, as is happening in other industries, the profit margins for the industry as a whole will grow. Competition in the industry will eventually, as in other industries, move from competition between companies to competition between supply chains. The construction industry supply chain boundaries are different to other industries and so is the final product. There are a few process models in the literature, but none offers a view on how the claims management process interacts with the other parties. The function presented in this dissertation treats claims management in an integrated way regarding the supply chain actors, not only focusing on the convulsive handling of a claim *per se*, but proposing a reference model that proactively, through the development of strategic processes, and reactively, through the development of operational processes, manages any such disruptive event. This is an innovative function that builds on existing models in the literature, enhances these models with previously undocumented practices, and connects claims to supply chain management in construction projects.

In practice, the proposed reference model can provide a guideline for handling supply chain processes in actual projects. The processes described can be used as contractual obligations that can be asserted on the implicated parties by the contractor. This does not necessarily carry an oppressive hue, but more likely can provide a tool for process standardisation across the construction industry. This mainly benefits the contractor because of the amount of parties it comes in contact with during a construction project, but it also provides a knowledge transfer opportunity for small and medium companies that do not have the internal capacity to manage organisation knowledge on their own. The reference model can be of use to worksite engineers, superintendents, planners and work crews that need to streamline worksite operations. Its effectiveness can be amplified when used in CM-GC projects. Furthermore, managers that wish to improve quality control through process mapping and improvement may find the proposed reference model as a good starting tool. General contractors, regardless of size, that participate in public or private projects can implement the proposed reference model in order to improve their relationships with clients and suppliers and optimise their profits through supply chain management improvement across their project portfolio. Finally, contractors that are interested in entering new markets with mature competitors or participating in tenders with strict criteria set by the client can benefit from the adoption of the proposed reference model by identifying processes and functions that require improvement in order to gain a competitive position in either the market or the tender.

Despite the anticipated benefits of the use of this reference model, there are still steps to be taken in the direction of streamlined process management in construction. The contractor may be the key player in the construction supply chain, but the clients are the ones generating demand and a similar reference model focusing on their side should be developed. Suppliers, mainly small and medium companies that represent the majority of the construction industry, provide the link between construction contractors and other industries. The effect of claims on the suppliers and the interactions between suppliers and the supply chains of other industries should be modelled in order to provide a complete reference model for the majority of the construction industry. Finally, process reference models can provide guidelines to implementation of IT systems. The effects of the application of the specific reference model on decisions to adopt IT systems that can support the communication of construction supply chain parties have to be examined.

There is one basic limitation of this work. The reference model focusses on vertical supply chain relationships and does not study horizontal ones. This means that its applicability in cases of PPP projects or other cases of contractor alliances is not guaranteed. Despite the fact that the studied literature draws from a global pool, interviews (aside from the claims and KPI themes) were conducted with representatives of Greek construction companies. The fact that in some cases international background was available does not allow for the precise and complete inclusion of practices in other countries. Another limitation of this research is the focus on mainstream construction markets. The particularities of niche construction markets were not studied. Furthermore, the reference model focuses on contractors and does not include actions that are performed by other parties; their actions are considered a black box.

Further research is required in order to expand the reference model with risk, decision and organisational views. The risk view can identify management risks related to strategic processes (and their sources – internal, external, environmental) as construction companies are notorious for their extensive risk catalogues used in their operational processes. This means that the development of a risk evaluation process could help contractors identify their more risk and claim prone tasks. This could lead to the identification of processes that require immediate attention and managers may direct resources to such processes more efficiently. A robust risk view can contribute to more efficient risk sharing or mitigating, depending on the relationship type associated with each client/supplier. Furthermore, future research on the risk view should focus on understanding how network structures affect risks and risk related processes as each supply chain partner treats risks differently. Risks are tightly related to decisions at both a strategic and operational level. The decision view can study mathematical models that can be adopted, for demand management in particular and other decision points in general. The organisational view can analytically study the responsibilities that correspond to each position in a construction company's organisational chart. Furthermore, the applicability of the reference model to construction companies operating in niche markets should be studied. In order to make the most of the capabilities that BIM software offers the integration of such tools and interfaces with the existing functions should be developed in the future. Finally, in order for the reference model to provide a precise depiction of construction supply chain relationships, the views of clients, suppliers and horizontally implicated contractors should be studied.

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Appendix I – Interview Questionnaires

English version

Questionnaire 1
Interview aims
One of the trends in concurrent construction literature is management of projects through supply chain management principles. A project is seen as the product of a complex production process that is dominated by the actions and decisions of the main contractor. In the research context of the proposed thesis, a process reference model developed for the manufacturing industry is being adapted to the particularities of the construction industry. In this model, determining supply chain strategies and performance measurement are considered as functions that affect project supply chains. Processes in the model are currently based on data that have been collected through a thorough literature research. This interview aims to collect real life data related to the aforementioned functions and compare them to the data available in the literature. This comparison will result in the following: 1) confirmation of data collected from the literature, 2) further analysis of the processes created and, 3) recording of best practices that literature is lacking.

Questions
1) Do construction companies develop strategies for their management processes (client relationship management, supplier relationship management, new project development) of their supply chains (Figure 1)?
2) Do construction companies develop strategies for their core processes (demand management, work package management, construction flow management, claims management) of their supply chains (Figure 2)?
3) What methods do construction companies use to measure the success of the selected strategies?
4) Do construction companies analyse their process maturity (e.g. use of SPICE framework)? How close to reality is Figure 3?
5) Do construction companies measure their process performance? If not, how useful could a process such as the one depicted in Figure 4 be for the development of a performance indicator framework?
6) How often are construction companies obliged to adopt specific performance indicators specified by clients or suppliers?
7) According to your opinion, what is the extent of the impact that a lack of a robust strategy and its monitoring through performance indicators on the supply chains of each project? Furthermore, what is the impact of this lacking on construction company profitability?

Estimated duration
30-40 minutes

Figures to analyse

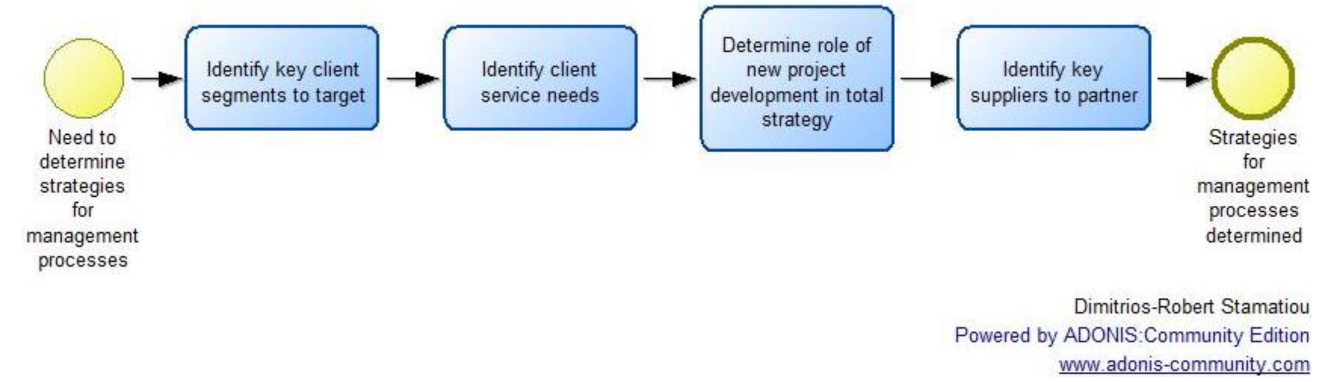

Figure 1

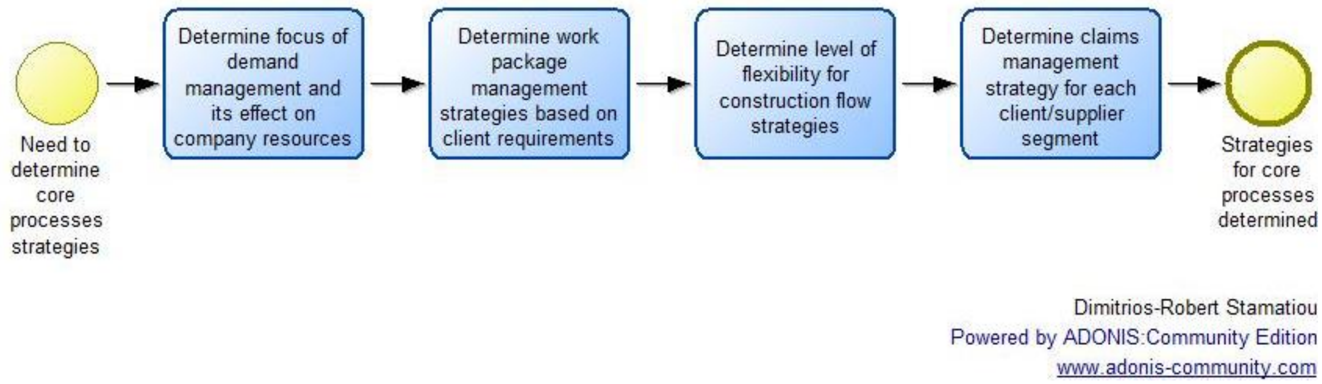

Figure 2

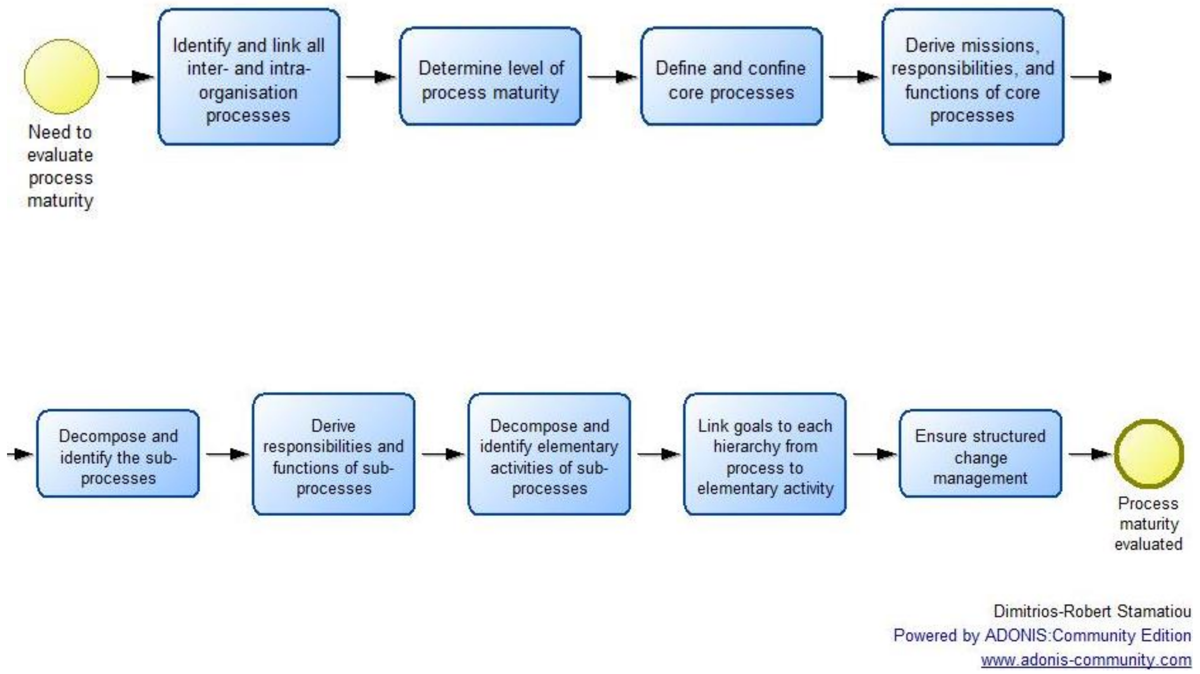

Figure 3

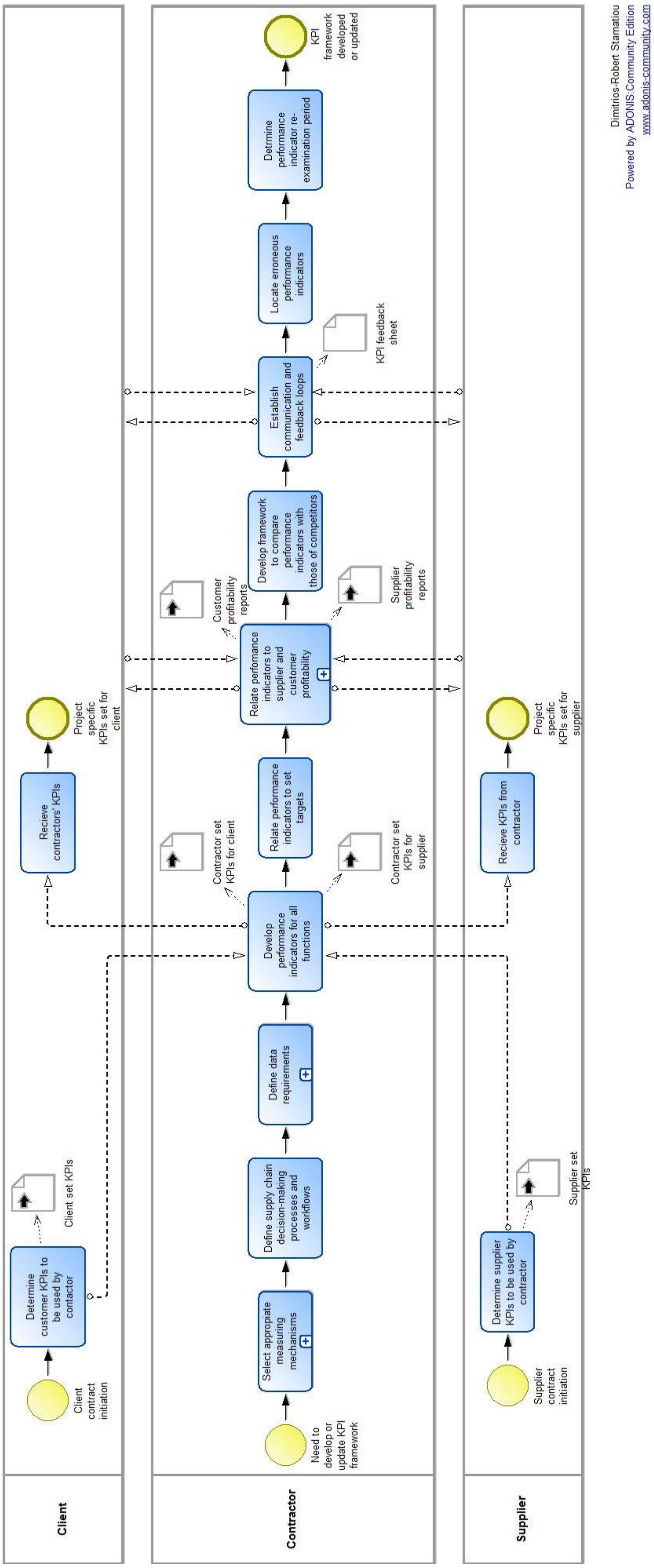
Client
Contractor
Supplier
Client contract initiation
Determine customer KPIs to be used by contactor
Client set KPIs
Recieve contractors' KPIs
Project specific KPIs set for client
Need to develop or update KPI framework
Select appropriate measuring mechanisms
Define supply chain decision-making processes and workflows
Define data requirements
Develop performance indicators for all functions
Contractor set KPIs for client
Contractor set KPIs for supplier
Relate performance indicators to set targets
Relate perfomance indicators to supplier and customer profitability
Customer profitability reports
Supplier profitability reports
Develop framework to compare performance indicators with those of competitors
Establish communication and feedback loops
KPI feedback sheet
Locate erroneous performance indicators
Detrmine performance indicator re-examination period
KPI framework developed or updated
Supplier contract initiation
Determine supplier KPIs to be used by contractor
Supplier set KPIs
Recieve KPIs from contractor
Project specific KPIs set for supplier
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Figure 4

Questionnaire 2

Interview aims

One of the trends in concurrent construction literature is management of projects through supply chain management principles. A project is seen as the product of a complex production process that is dominated by the actions and decisions of the main contractor. In the research context of the proposed thesis, a process reference model developed for the manufacturing industry is being adapted to the particularities of the construction industry. In this model, client and supplier relationship management are considered as functions that affect project supply chains. Processes in the model are currently based on data that have been collected through a thorough literature research. This interview aims to collect real life data related to the aforementioned functions and compare them to the data available in the literature. This comparison will result in the following: 1) confirmation of data collected from the literature, 2) further analysis of the processes created and, 3) recording of best practices that literature is lacking.

Questions

1) Do construction companies categorise their clients? What criteria are used for this categorisation? Are there internal groups in the company that manage clients according to their categorisation?
2) Do construction companies maintain records for each client? Is a client's history examined before making the decision to join a tendering process? Are client accounts examined for opportunities of a closer collaboration?
3) What is a typical contract negotiation process with the client (Figure 1)? Are contracts updated during the duration of the project in the case problems occur? Can suppliers intervene in negotiations with the client?
4) Is there a "client service" department that manages different events (e.g. changes, claims) that may occur during the duration or after the completion of the project (if this is included in the contract)?
5) Do construction companies categorise their suppliers? What criteria are used for this categorisation? Are there internal groups in the company that manage suppliers according to their categorisation?
6) Do construction companies maintain records for each supplier? Is a supplier's history examined before making the decision to assign them a contract? Are supplier accounts examined for opportunities of a closer collaboration?
7) What is a typical contract negotiation process with the supplier (Figure 2)? Are contracts updated during the duration of the project in the case problems occur? Can clients intervene in negotiations with the supplier?
8) Are client and supplier relationship management processes monitored with performance indicators? Is the profit/loss that the selection of a specific client or supplier measured?

Estimated duration

50-60 minutes

Figures to analyse

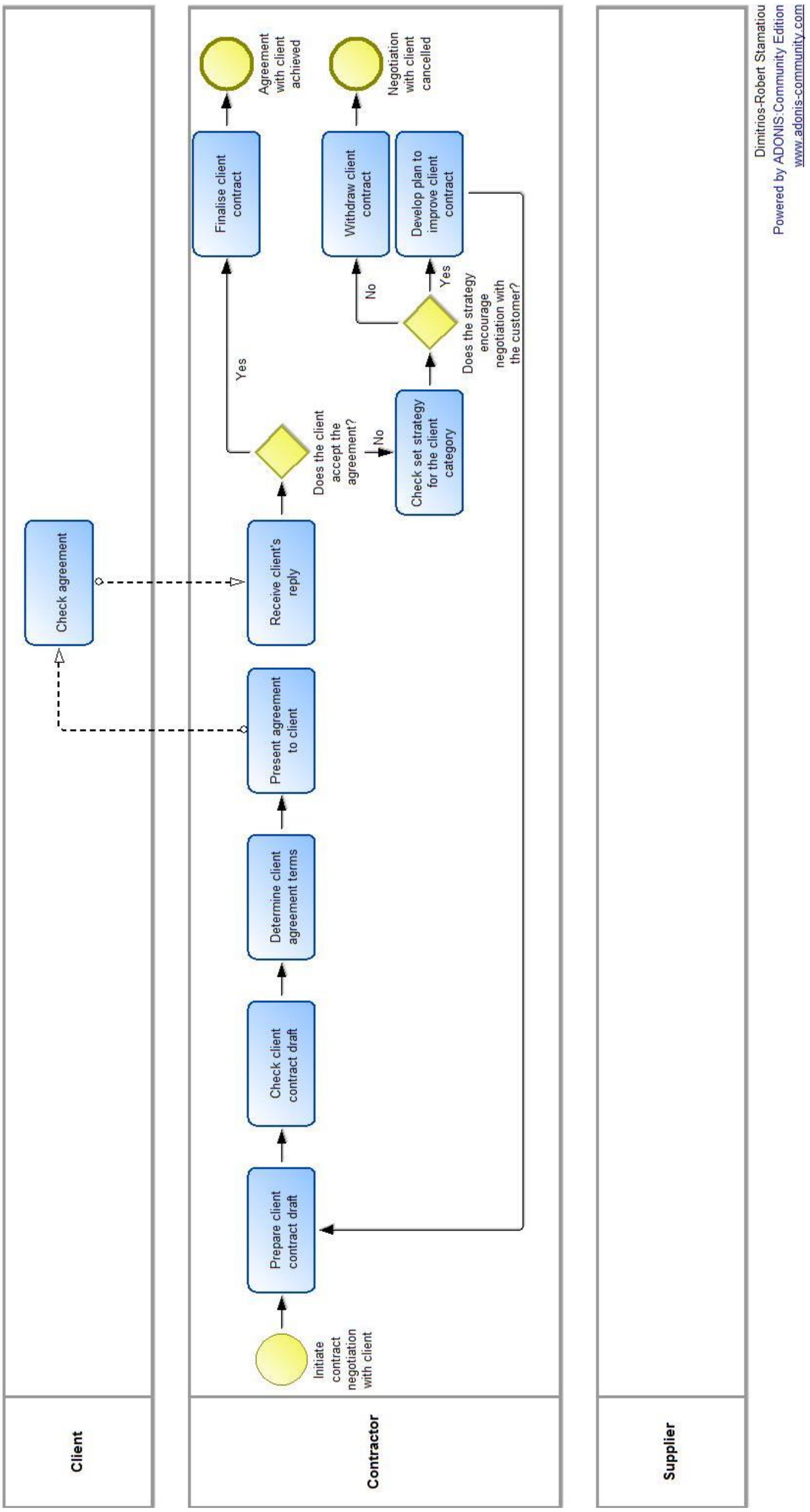
Client
Contractor
Supplier
Check agreement
Initiate contract negotiation with client
Prepare client contract draft
Check client contract draft
Determine client agreement terms
Present agreement to client
Receive client's reply
Does the client accept the agreement?
Yes
No
Check set strategy for the client category
Does the strategy encourage negotiation with the customer?
No
Yes
Finalise client contract
Withdraw client contract
Develop plan to improve client contract
Agreement with client achieved
Negotiation with client cancelled
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Figure 1

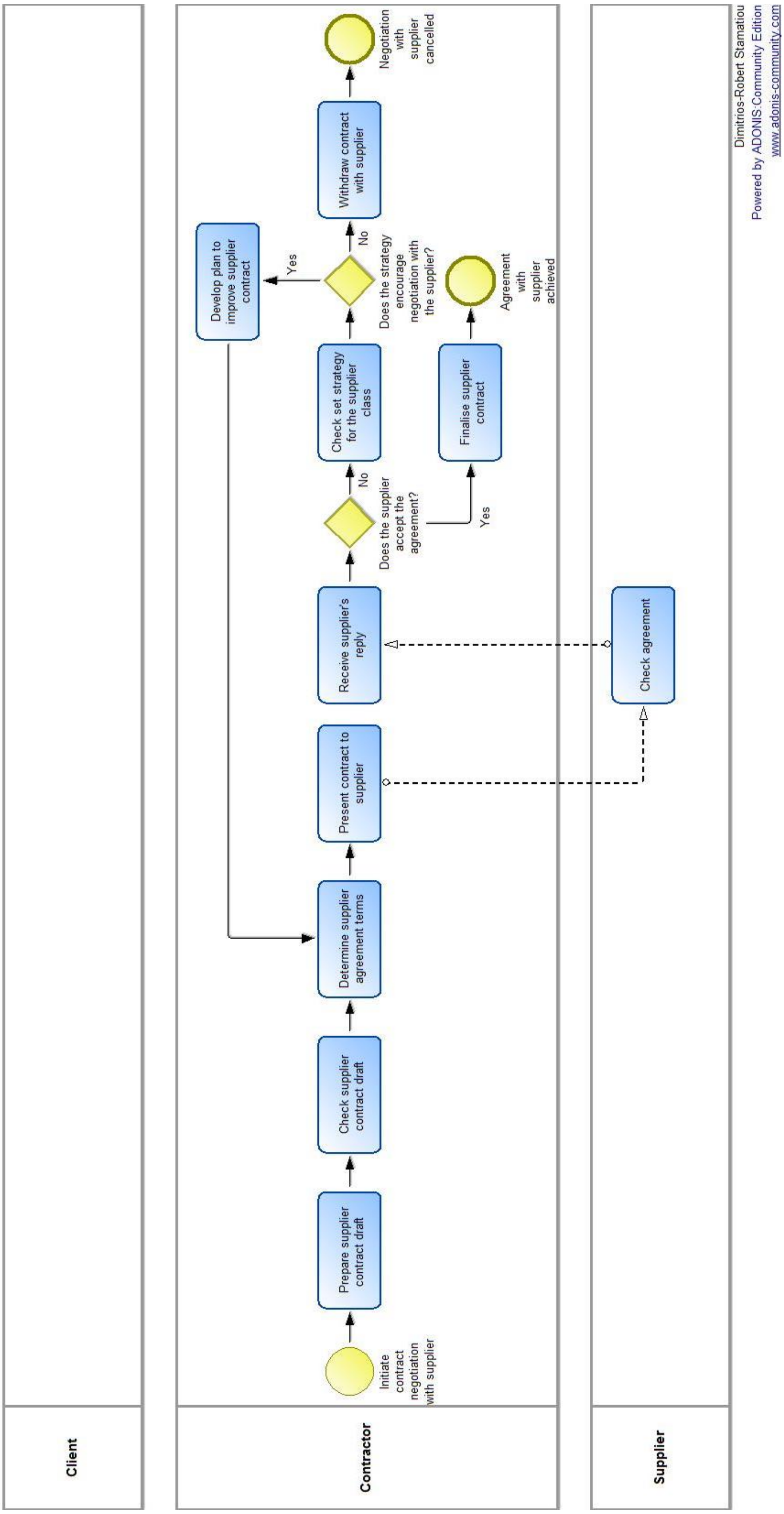
Client
Contractor
Supplier
Initiate contract negotiation with supplier
Prepare supplier contract draft
Check supplier contract draft
Determine supplier agreement terms
Present contract to supplier
Receive supplier's reply
Check agreement
Does the supplier accept the agreement?
Yes
No
Finalise supplier contract
Agreement with supplier achieved
Check set strategy for the supplier class
Does the strategy encourage negotiation with the supplier?
Yes
No
Develop plan to improve supplier contract
Withdraw contract with supplier
Negotiation with supplier cancelled
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Figure 2

Questionnaire 3

Interview aims

One of the trends in concurrent construction literature is management of projects through supply chain management principles. A project is seen as the product of a complex production process that is dominated by the actions and decisions of the main contractor. In the research context of the proposed thesis, a process reference model developed for the manufacturing industry is being adapted to the particularities of the construction industry. In this model, demand management and new project development are considered as functions that affect project supply chains. Processes in the model are currently based on data that have been collected through a thorough literature research. This interview aims to collect real life data related to the aforementioned functions and compare them to the data available in the literature. This comparison will result in the following: 1) confirmation of data collected from the literature, 2) further analysis of the processes created and, 3) recording of best practices that literature is lacking.

Questions

1) Can you confirm that demand management is a function related to construction supply chain management?
2) What are the usual demand data sources?
3) What is a typical demand forecast process in the construction industry (Figure 1)?
4) Do construction companies need to reduce demand variability or increase their flexibility in the face of demand swifts? How accurate is the process depicted in Figure 2?
5) Can you confirm that new project development is a function related to construction supply chain management?
6) What are the usual sources for new project development?
7) What is a typical process for determining and evaluating new projects (Figure 3)?
8) Are the effects of new project development on the company's personnel evaluated?
9) What is a typical new project development process (Figure 4);
10) What factors contribute to the decision to subcontract specific work packages?
11) How much do IT systems such as BIM (Building Information Modelling) contribute to the development of new projects? Do you believe that subcontractor access to such company systems offers benefits to the coordination of such processes?
12) Are these processes monitored through performance indicators?

Estimated duration

50-60 minutes

Figures to analyse

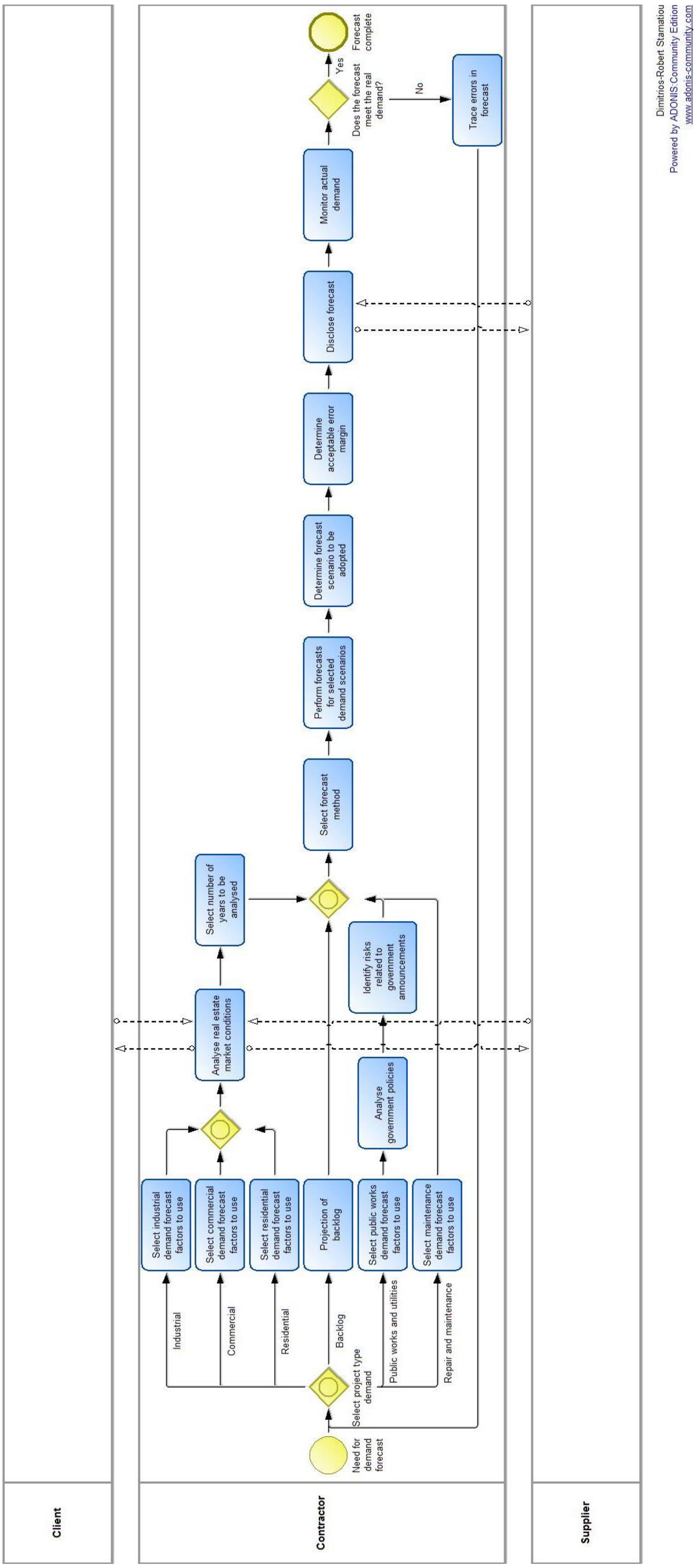
Client
Contractor
Supplier
Need for demand forecast
Select project type demand
Industrial
Commercial
Residential
Backlog
Public works and utilities
Repair and maintenance
Select industrial demand forecast factors to use
Select commercial demand forecast factors to use
Select residential demand forecast factors to use
Projection of backlog
Select public works demand forecast factors to use
Select maintenance demand forecast factors to use
Analyse government policies
Analyse real estate market conditions
Identify risks related to government announcements
Select number of years to be analysed
Select forecast method
Perform forecasts for selected demand scenarios
Determine forecast scenario to be adopted
Determine acceptable error margin
Disclose forecast
Monitor actual demand
Does the forecast meet the real demand?
Yes
No
Forecast complete
Trace errors in forecast
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Figure 1

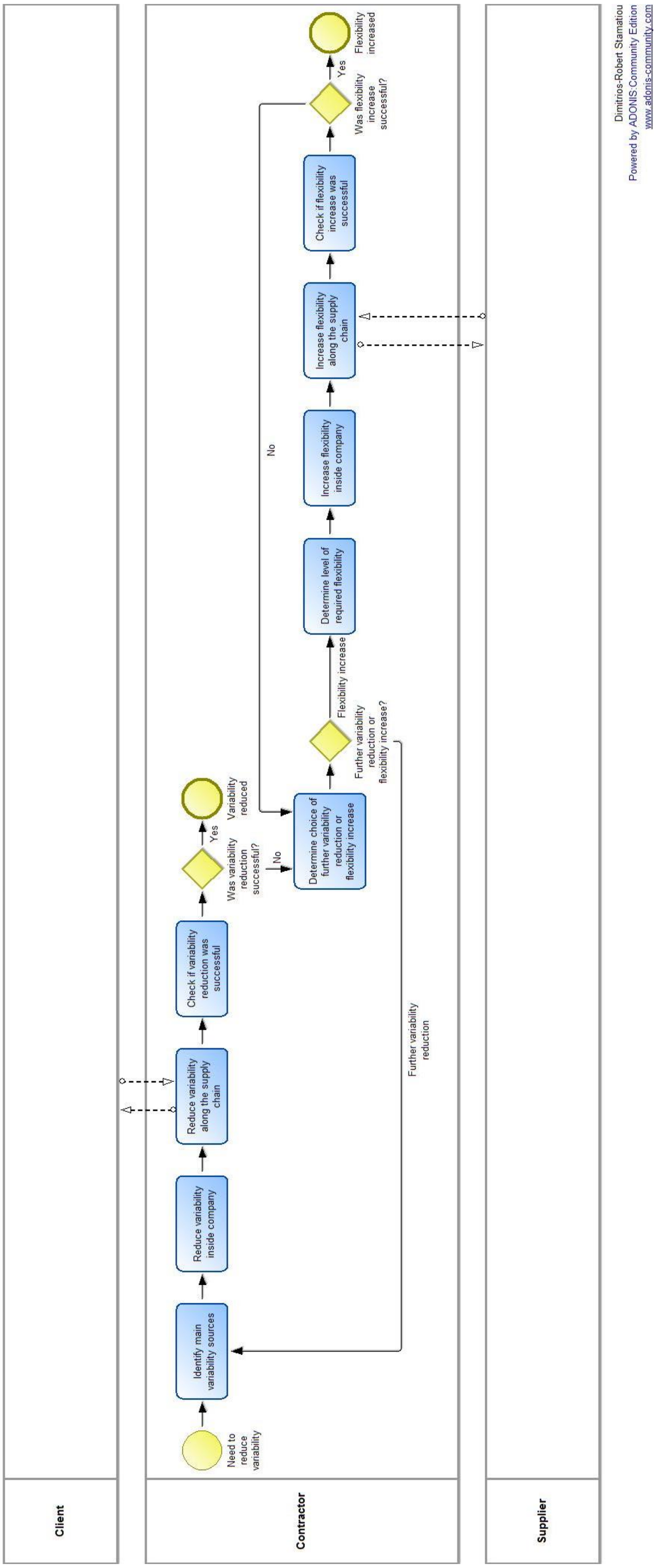
Client
Contractor
Supplier
Need to reduce variability
Identify main variability sources
Reduce variability inside company
Reduce variability along the supply chain
Check if variability reduction was successful
Was variability reduction successful?
Yes
No
Variability reduced
Determine choice of further variability reduction or flexibility increase
Further variability reduction or flexibility increase?
Further variability reduction
Flexibility increase
Determine level of required flexibility
Increase flexibility inside company
Increase flexibility along the supply chain
Check if flexibility increase was successful
Was flexibility increase successful?
Flexibility increased
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Figure 2

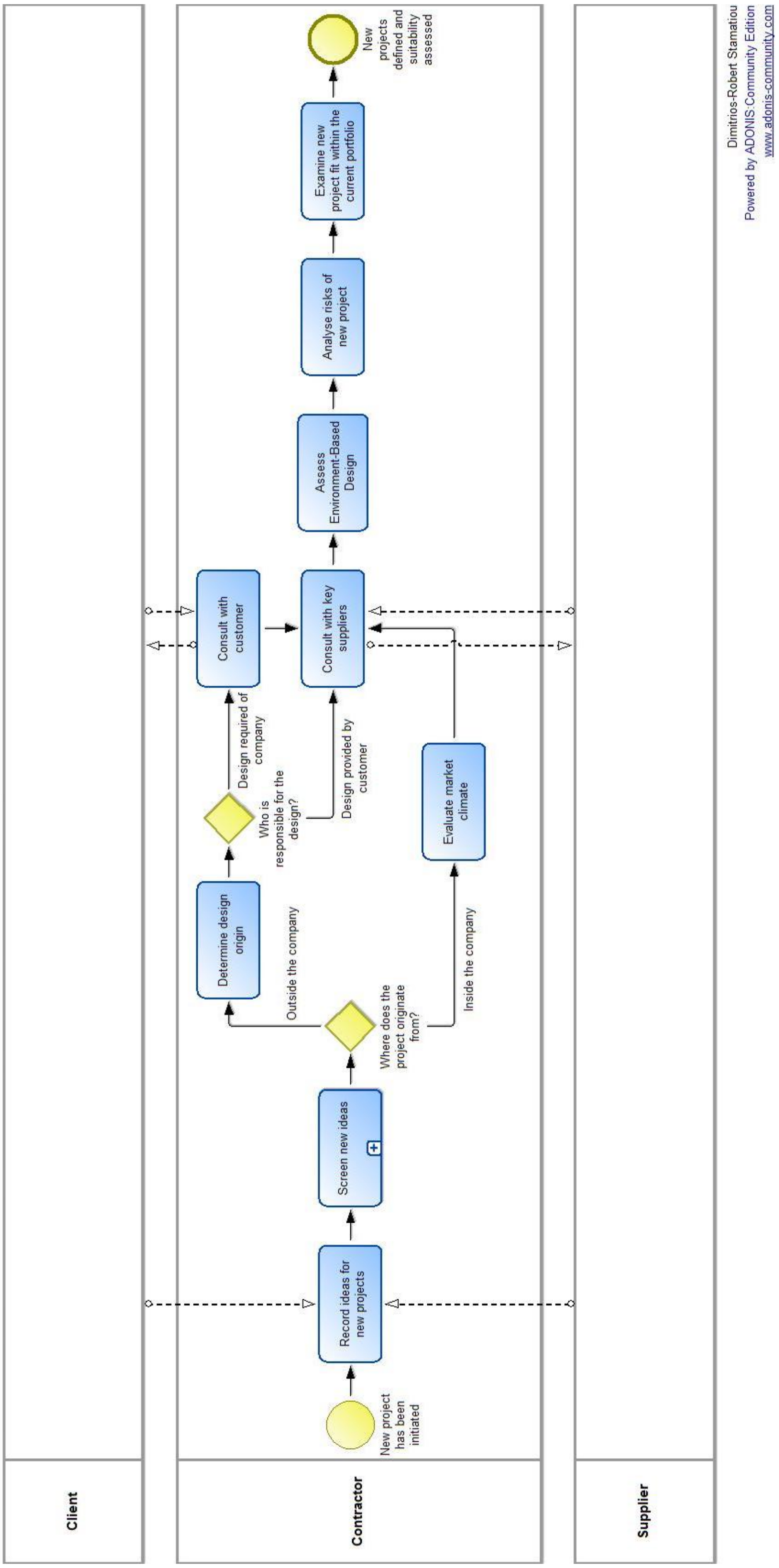
Client
Contractor
Supplier
New project has been initiated
Record ideas for new projects
Screen new ideas
Where does the project originate from?
Outside the company
Inside the company
Determine design origin
Who is responsible for the design?
Design required of company
Design provided by customer
Evaluate market climate
Consult with customer
Consult with key suppliers
Assess Environment-Based Design
Analyse risks of new project
Examine new project fit within the current portfolio
New projects defined and suitability assessed
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Figure 3

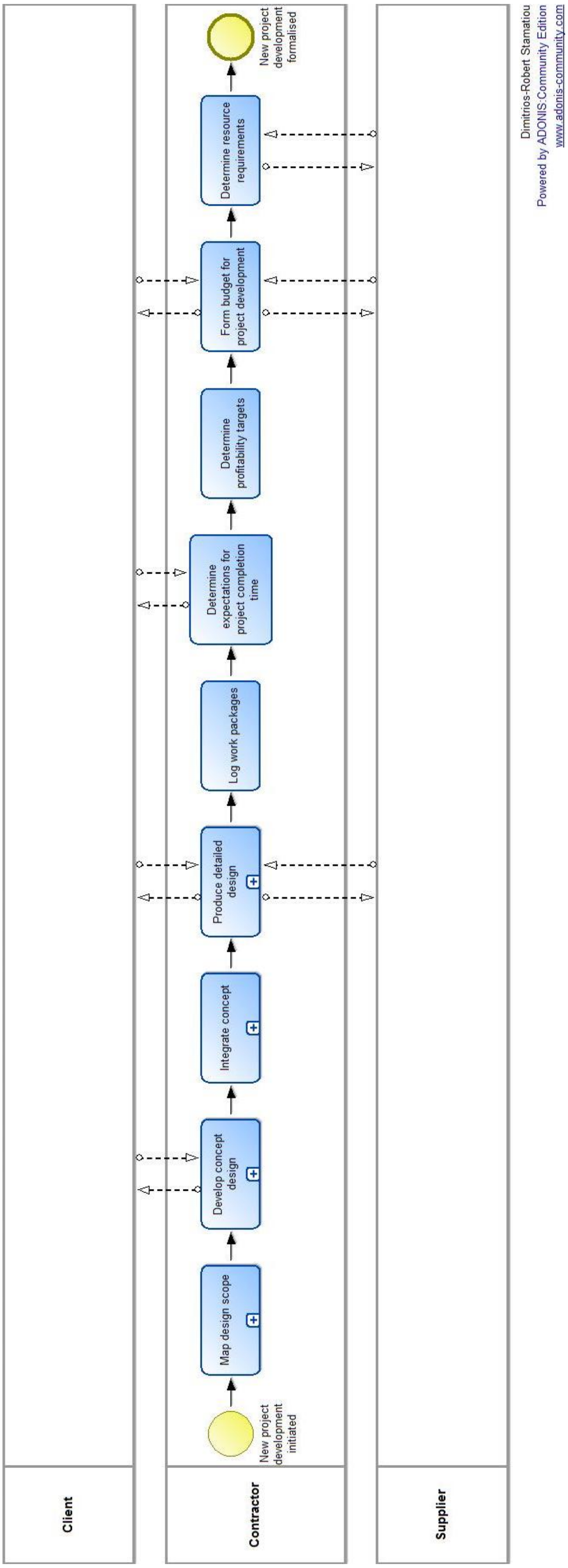
Client
Contractor
Supplier
New project development initiated
Map design scope
Develop concept design
Integrate concept
Produce detailed design
Log work packages
Determine expectations for project completion time
Determine profitability targets
Form budget for project development
Determine resource requirements
New project development formalised
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Figure 4

Questionnaire 4

Interview aims

One of the trends in concurrent construction literature is management of projects through supply chain management principles. A project is seen as the product of a complex production process that is dominated by the actions and decisions of the main contractor. In the research context of the proposed thesis, a process reference model developed for the manufacturing industry is being adapted to the particularities of the construction industry. In this model, work package management and construction flow management are considered as functions that affect project supply chains. Processes in the model are currently based on data that have been collected through a thorough literature research. This interview aims to collect real life data related to the aforementioned functions and compare them to the data available in the literature. This comparison will result in the following: 1) confirmation of data collected from the literature, 2) further analysis of the processes created and, 3) recording of best practices that literature is lacking.

Questions

1) Can you confirm that work package management is a function related to construction supply chain management?
2) What process is typically followed to prepare a work package for execution (Figure 1)?
3) What process is typically followed to monitor work packages under execution (Figure 2)?
4) What process is typically followed for documentation handling and what documentation is contained in a work package (Figure 3)?
5) Can you confirm that construction flow management is a function related to construction supply chain management?
6) What process is typically followed for long-term resource planning and task scheduling (Figure 4)?
7) What process is typically followed for short-term resource planning and task scheduling (Figure 5)?
8) What process is typically followed for work execution (Figure 6)?
9) What are the most common problems that arise in work package management?
10) How big a problem does lack of space on the work space pose? How much does poor space scheduling increase project costs? How efficient is the solution of distribution centers against such problems?
11) How much do IT systems such as BIM (Building Information Modelling) contribute to the work package and construction flow management? Do you believe that subcontractor access to such company systems offers benefits to the coordination of such processes?
12) Are these processes monitored through performance indicators?

Estimated duration

60-70 minutes

Figures to analyse

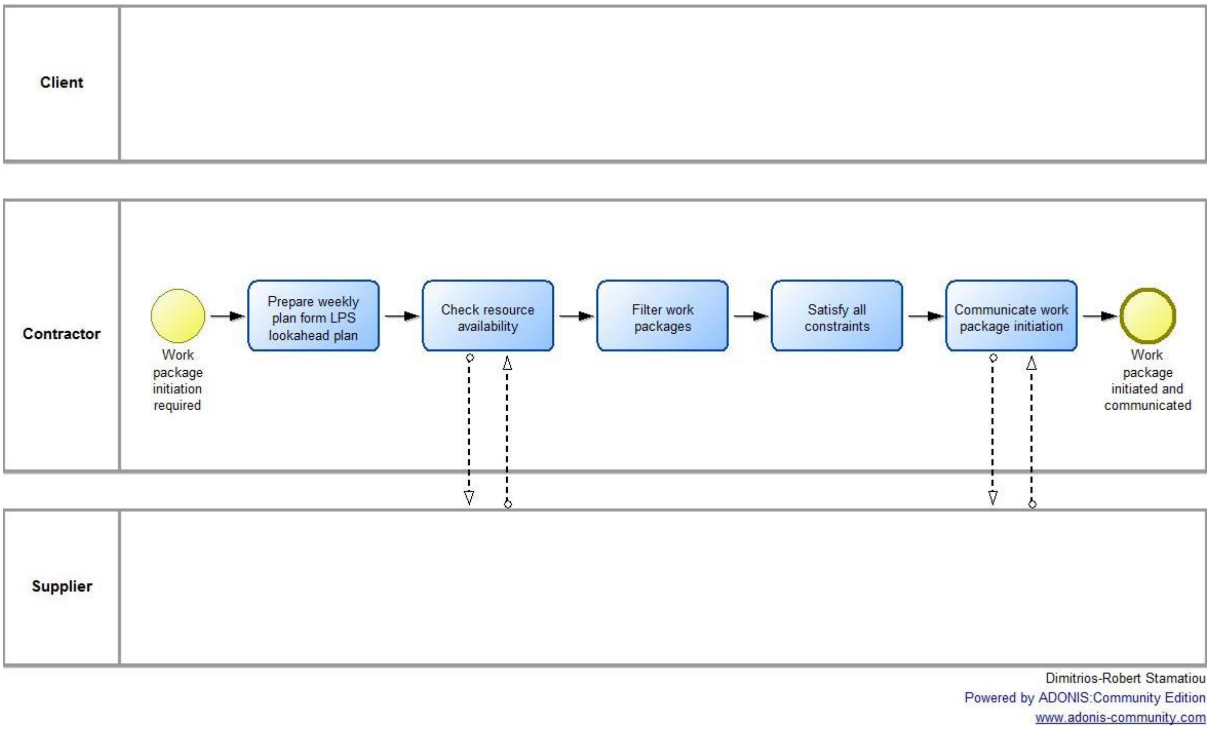

Figure 1

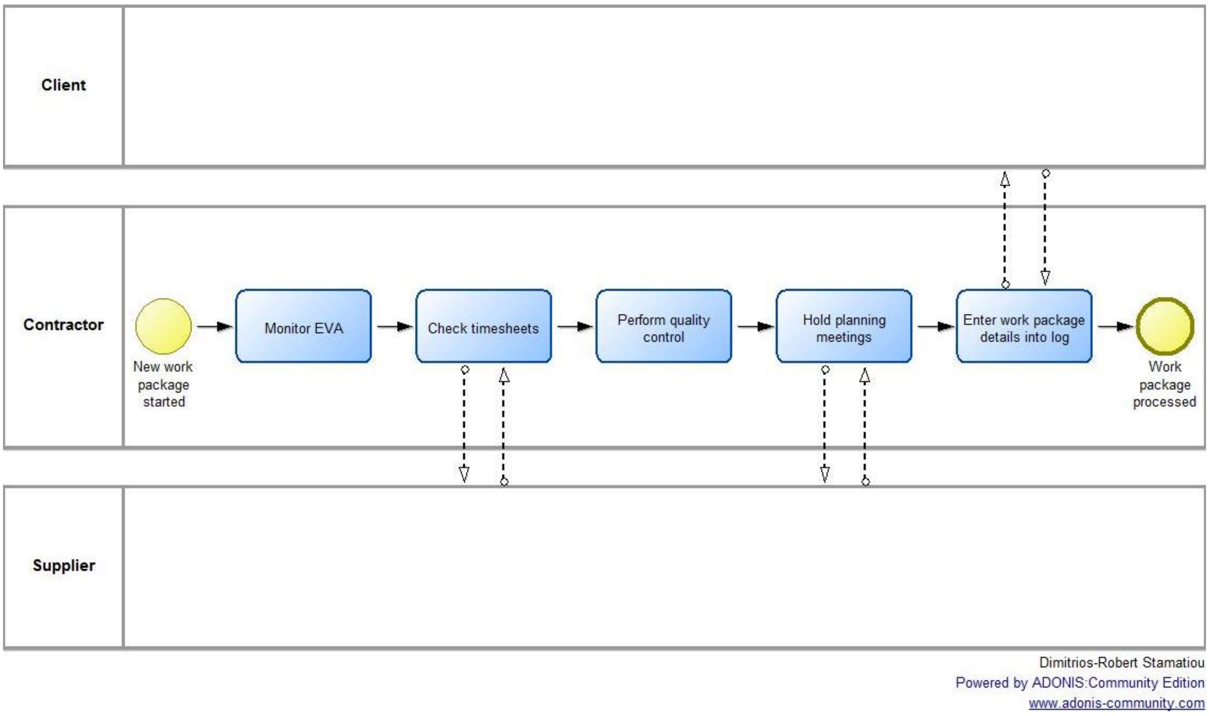

Figure 2

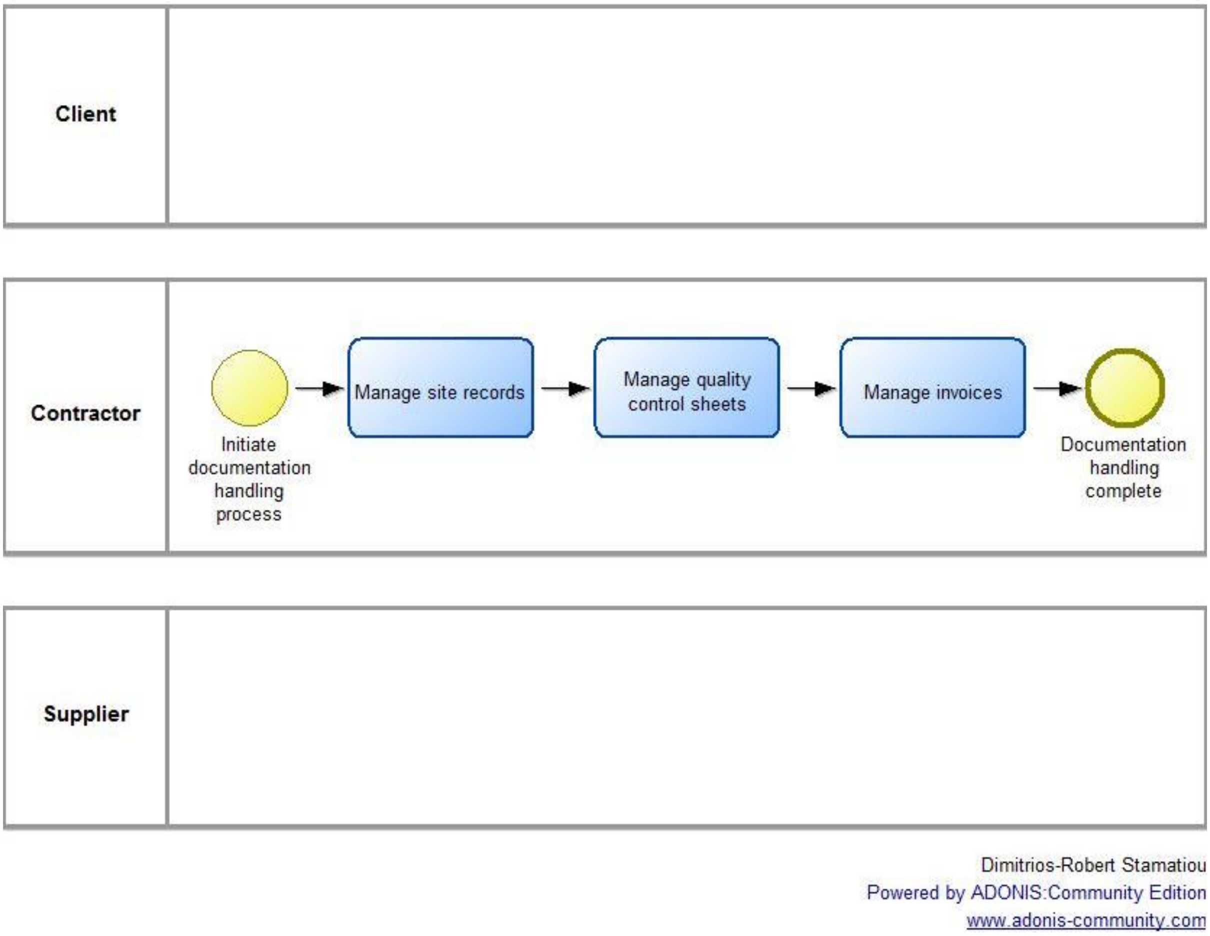
Client
Contractor
Initiate documentation handling process
Manage site records
Manage quality control sheets
Manage invoices
Documentation handling complete
Supplier
Dimitrios-Robert Stamatiou
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Figure 3

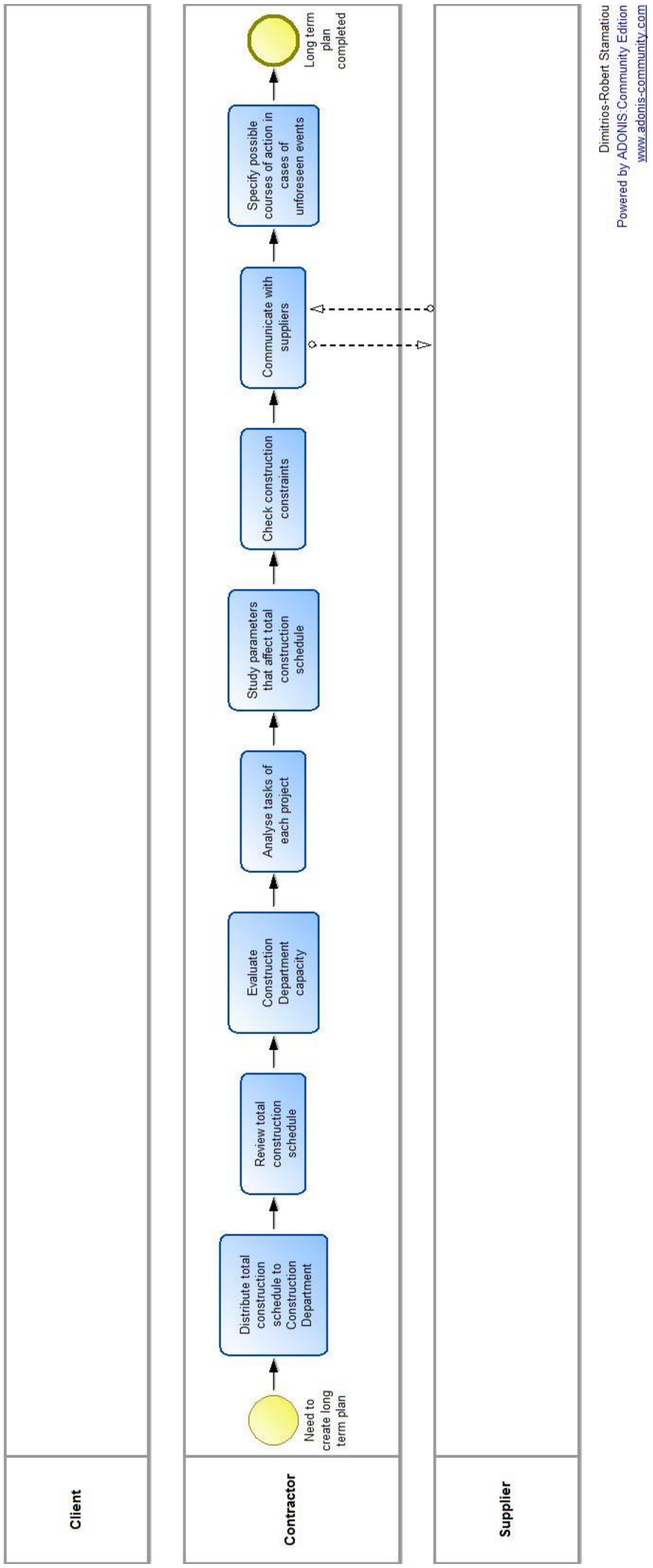
Client
Contractor
Supplier
Need to create long term plan
Distribute total construction schedule to Construction Department
Review total construction schedule
Evaluate Construction Department capacity
Analyse tasks of each project
Study parameters that affect total construction schedule
Check construction constraints
Communicate with suppliers
Specify possible courses of action in cases of unforeseen events
Long term plan completed
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Figure 4

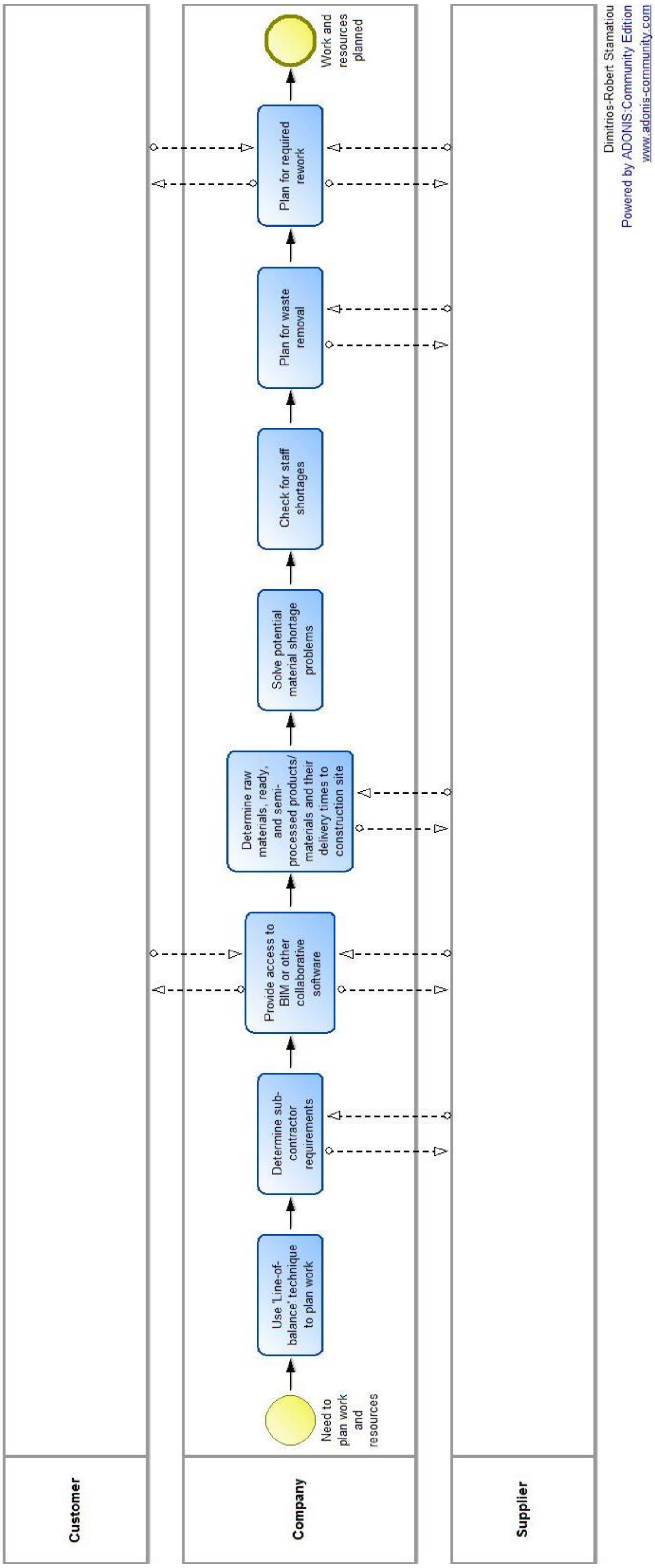
Customer
Company
Supplier
Need to plan work and resources
Use 'Line-of-balance' technique to plan work
Determine sub-contractor requirements
Provide access to BIM or other collaborative software
Determine raw materials, ready, and semi-processed products/ materials and their delivery times to construction site
Solve potential material shortage problems
Check for staff shortages
Plan for waste removal
Plan for required rework
Work and resources planned
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Figure 5

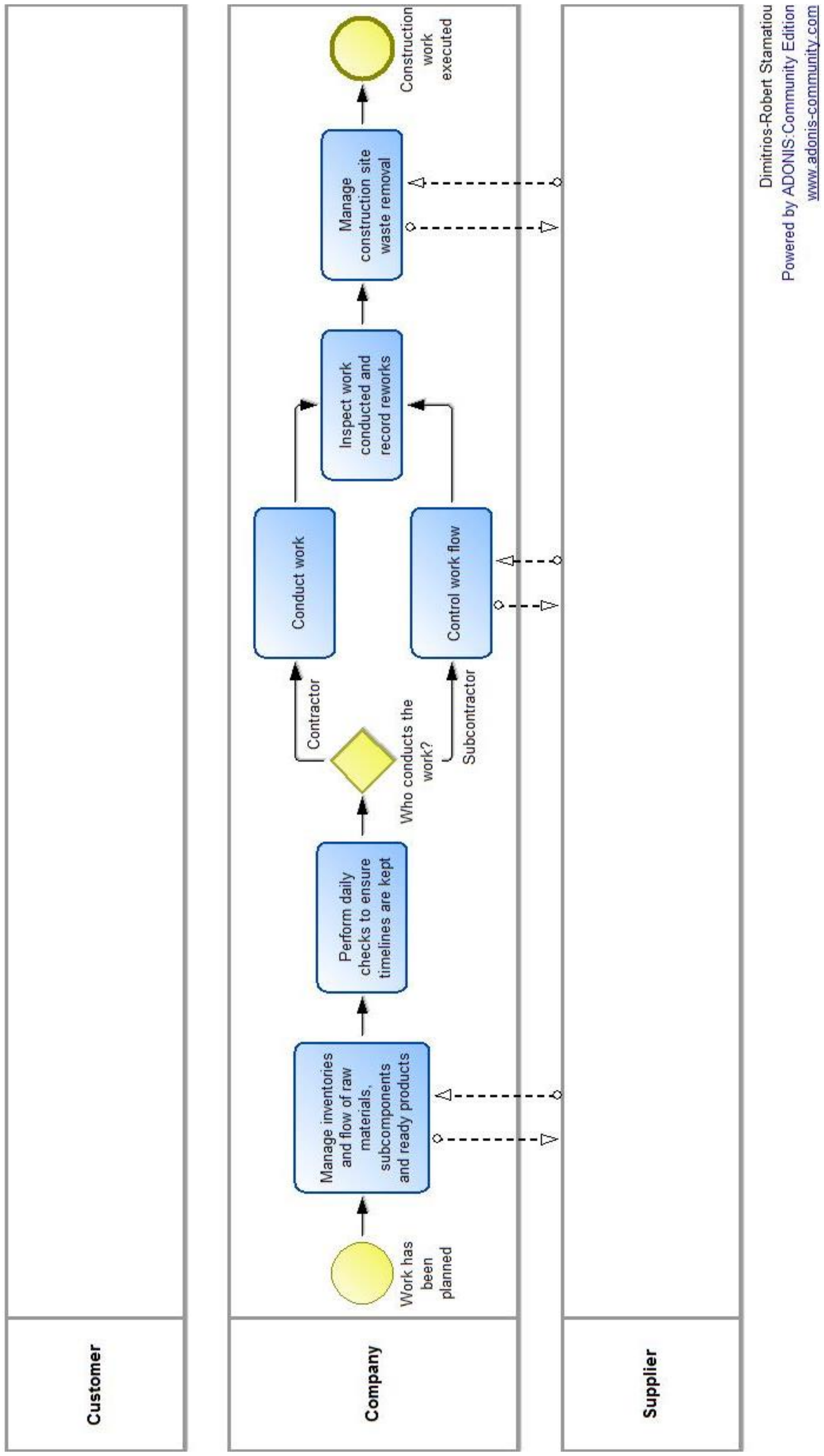
Customer
Company
Supplier
Work has been planned
Manage inventories and flow of raw materials, subcomponents and ready products
Perform daily checks to ensure timelines are kept
Who conducts the work?
Contractor
Subcontractor
Conduct work
Control work flow
Inspect work conducted and record reworks
Manage construction site waste removal
Construction work executed
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Figure 6

Questionnaire 5

Interview aims

One of the trends in concurrent construction literature is management of projects through supply chain management principles. A project is seen as the product of a complex production process that is dominated by the actions and decisions of the main contractor. In the research context of the proposed thesis, a process reference model developed for the manufacturing industry is being adapted to the particularities of the construction industry. In this model, claims management is considered as a function that affects project supply chains. Processes in the model are currently based on data that have been collected through a thorough literature research. This interview aims to collect real life data related to the aforementioned functions and compare them to the data available in the literature. This comparison will result in the following: 1) confirmation of data collected from the literature, 2) further analysis of the processes created and, 3) recording of best practices that literature is lacking.

Questions

1) What is a typical claims management process?
2) How do you identify a claim?
3) Does your organisation have a set of guidelines related to the management of potential claims?
4) Is it common to study the long-term effect of a claim on the project?
5) What kind of documentation is typically used to substantiate a claim?
6) Besides time and/or monetary compensations, what other types of compensations exist in practice?
7) What is a typical negotiation preparation process?
8) What is a typical contract termination process?
9) Are claims management processes monitored with performance indicators? Yes or no and why? If yes, how is this performed?
10) How often do claims occur in projects?
11) In your personal opinion, how do claims affect a project's supply chain?
12) Do you believe that claims disrupt relationships between project actors?
13) Regarding claims, does your experience indicate a common approach to all project actors or are there actors who enjoy certain "privileges" due to a better relationship with the main contractor?
14) What fragment of claims is resolved without litigation and how common is litigation?

Estimated duration

60-70 minutes

KPI Questionnaire

Interview aims

One of the trends in concurrent construction literature is management of projects through supply chain management principles. A project is seen as the product of a complex production process that is dominated by the actions and decisions of the main contractor. In the research context of the proposed thesis, a process reference model developed for the manufacturing industry is being adapted to the particularities of the construction industry. In this model, performance measurement is considered a function that affects project supply chains. Processes in the model are currently based on data that have been collected through a thorough literature research. This interview aims to collect real life data related to the aforementioned functions and compare them to the data available in the literature. This comparison will result in the following: 1) confirmation of data collected from the literature, 2) further analysis of the processes created and, 3) recording of best practices that literature is lacking.

Questions

1) How close to reality is Figure 1 which represents the measurement of process maturity?
2) How close to reality Figure 2 which represents a process for the development of a performance indicator framework?
3) If you have any experience with consulting construction companies, what is their attitude towards process management and process performance measurement?

Estimated duration

30-40 minutes

Figures to analyse

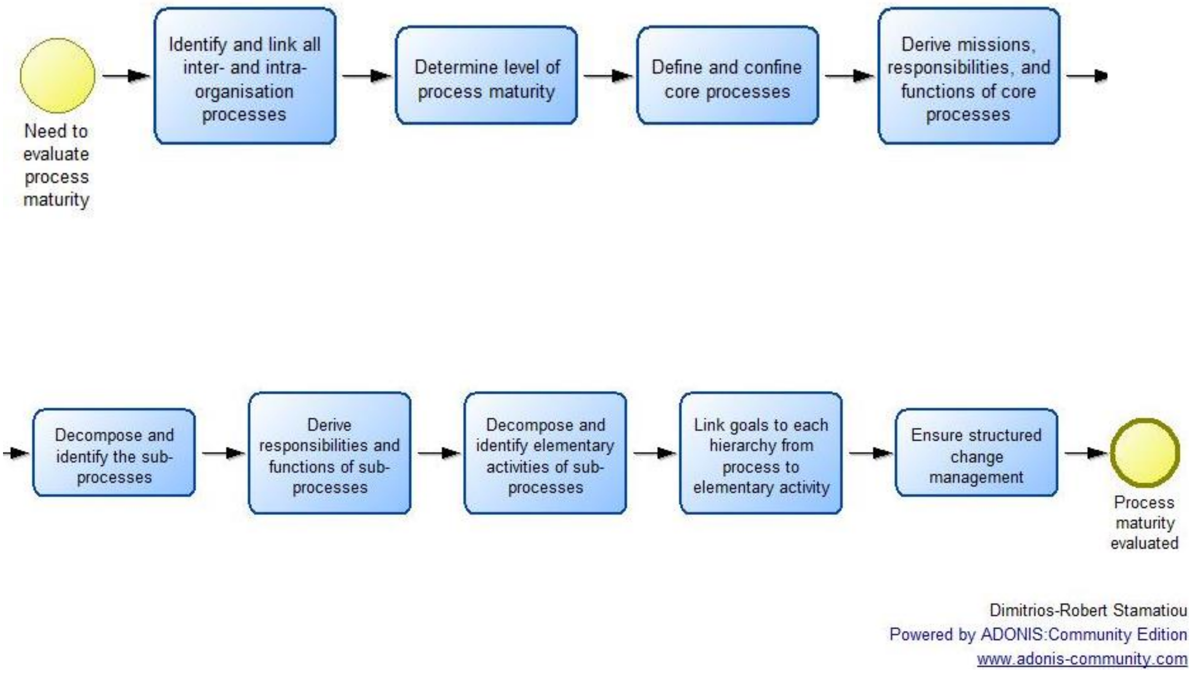

Figure 1

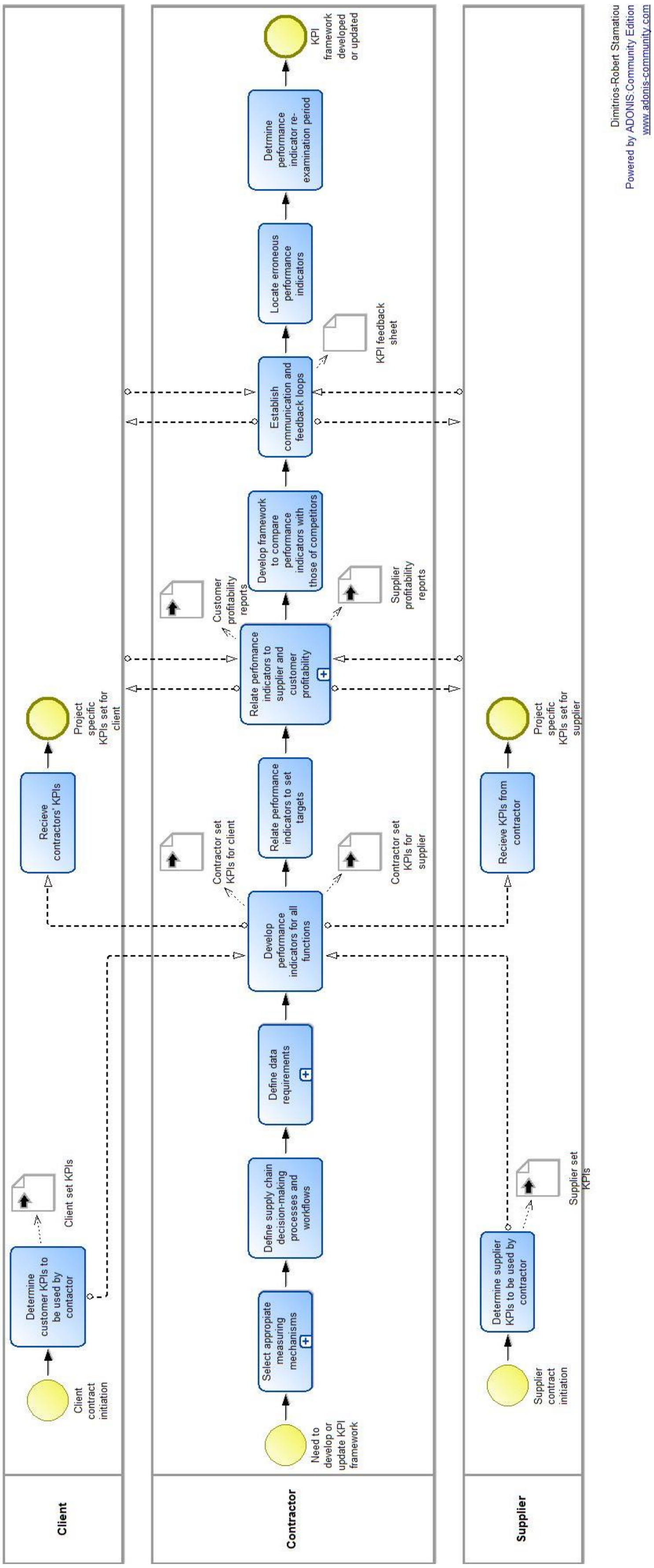
Client
Contractor
Supplier
Client contract initiation
Determine customer KPIs to be used by contactor
Client set KPIs
Recieve contractors' KPIs
Project specific KPIs set for client
Need to develop or update KPI framework
Select appropiate measuring mechanisms
Define supply chain decision-making processes and workflows
Define data requirements
Develop performance indicators for all functions
Contractor set KPIs for client
Contractor set KPIs for supplier
Relate performance indicators to set targets
Relate perfomance indicators to supplier and customer profitability
Customer profitability reports
Supplier profitability reports
Develop framework to compare performance indicators with those of competitors
Establish communication and feedback loops
KPI feedback sheet
Locate erroneous performance indicators
Detrmine performance indicator re-examination period
KPI framework developed or updated
Supplier contract initiation
Determine supplier KPIs to be used by contractor
Supplier set KPIs
Recieve KPIs from contractor
Project specific KPIs set for supplier
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Figure 2

Greek version – Ελληνική εκδοχή

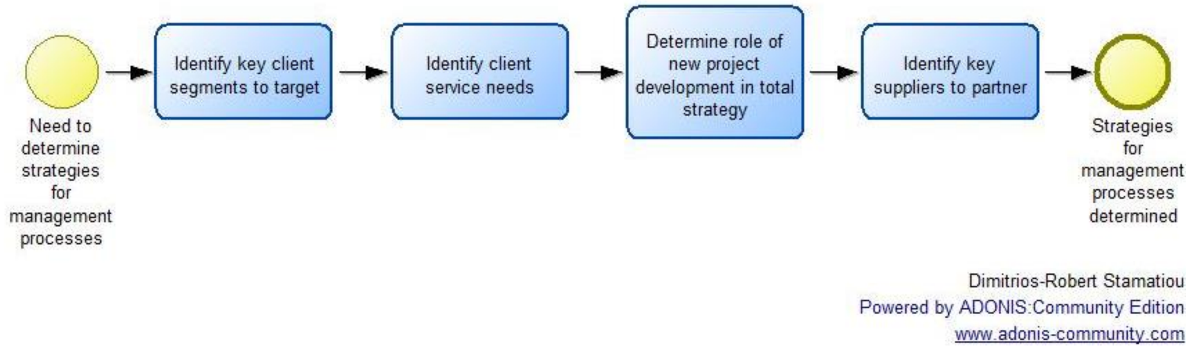
Ερωτηματολόγιο 1
Σκοπός συνέντευξης
Η σύγχρονη τάση στη βιβλιογραφία των κατασκευών είναι η διοίκηση των κατασκευαστικών έργων μέσα από αρχές της θεωρίας των εφοδιαστικών αλυσίδων. Το έργο αντιμετωπίζεται ως προϊόν μιας πολύπλοκης παραγωγικής διαδικασίας στην οποία κεντρικό ρόλο αναλαμβάνει ο κύριος εργολάβος. Στο πλαίσιο της έρευνας για την παρούσα διδακτορική διατριβή, προσαρμόζεται μοντέλο αναφοράς διαδικασιών διοίκησης εφοδιαστικής αλυσίδας που αναπτύχθηκε για την παραγωγική βιομηχανία στις ανάγκες του κατασκευαστικού κλάδου. Στο μοντέλο αυτό η διαμόρφωση στρατηγικής και η διαμόρφωση πλαισίου μέτρησης απόδοσης αντιμετωπίζονται ως οικογένειες διαδικασιών που επηρεάζουν την εφοδιαστική αλυσίδα του έργου. Προς το παρόν οι διαδικασίες του μοντέλου βασίζονται σε δεδομένα που έχουν συλλεχθεί μετά από ενδελεχή βιβλιογραφική έρευνα. Σκοπός της συνέντευξης είναι η συλλογή δεδομένων για τις παραπάνω διαδικασίες στην πραγματική ζωή και η σύγκριση των δεδομένων αυτών με τα βιβλιογραφικά δεδομένα. Τα αποτελέσματα της σύγκρισης χρησιμεύουν για: 1) επιβεβαίωση των δεδομένων που συλλέχθηκαν από τη βιβλιογραφία, 2) περεταίρω/ βαθύτερη ανάλυση των διαδικασιών που έχουν δημιουργηθεί και 3) καταγραφή βέλτιστων πρακτικών που δεν υπάρχουν στη βιβλιογραφία.

Ερωτήσεις

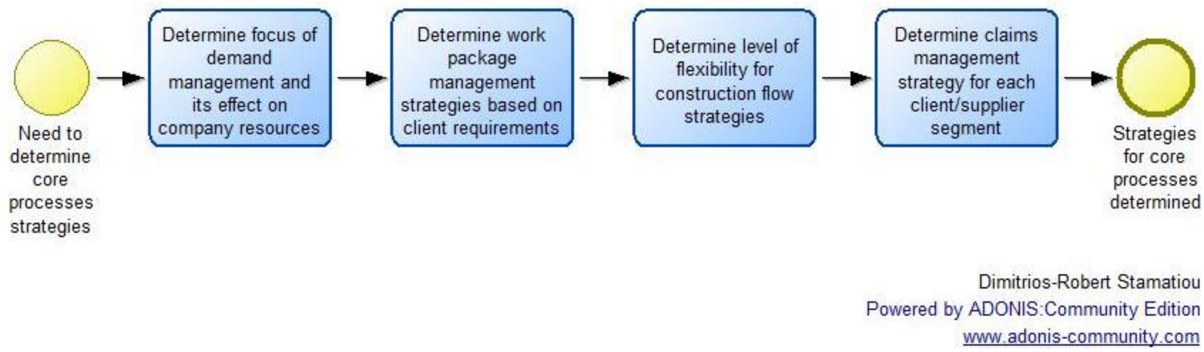
1) Οι κατασκευαστικές εταιρείες ακολουθούν τακτικές για την ανάπτυξη στρατηγικών για τις διαχειριστικές διαδικασίες (διαχείριση πελατών, διαχείριση προμηθευτών, ανάπτυξη νέων έργων) της εφοδιαστικής αλυσίδας (Εικόνα 1);
2) Οι κατασκευαστικές εταιρείες ακολουθούν τακτικές για την ανάπτυξη στρατηγικών για τις εκτελεστικές διαδικασίες (διαχείριση ζήτησης, διαχείριση πακέτων εργασίας, διαχείριση ροής κατασκευής, διαχείριση αξιώσεων) της εφοδιαστικής αλυσίδας (Εικόνα 2);
3) Με τι τρόπο παρακολουθούν την επιτυχία των ακολουθούμενων στρατηγικών οι κατασκευαστικές εταιρείες;
4) Οι κατασκευαστικές εταιρείες αναλύουν την ωριμότητα των διαδικασιών τους (πχ με εργαλεία όπως το SPICE); Πόσο κοντά στην πραγματικότητα είναι η διαδικασία στην Εικόνα 3;
5) Οι κατασκευαστικές εταιρείες μετράνε την απόδοση των διαδικασιών τους; Αν όχι, πόσο χρήσιμη φαίνεται η διαδικασία που απεικονίζεται στην Εικόνα 4 για τη δημιουργία ενός πλαισίου δεικτών απόδοσης;
6) Πόσο συχνά αναγκάζονται οι κατασκευαστικές εταιρείες να υιοθετήσουν δείκτες απόδοσης που τους επιβάλουν οι πελάτες ή οι προμηθευτές;
7) Πόσο μεγάλη επίπτωση έχει, κατά τη γνώμη σας, η έλλειψη στιβαρής στρατηγικής και η παρακολούθησή της μέσω δεικτών απόδοσης στις διαδικασίες διαχείρισης της εφοδιαστικής αλυσίδας των έργων; Αντίστοιχα, πόσο μεγάλη επίπτωση έχουν αυτές οι ελλείψεις, κατά τη γνώμη σας, στην κερδοφορία των κατασκευαστικών εταιρειών;

Εκτιμώμενη διάρκεια
30-40 λεπτά

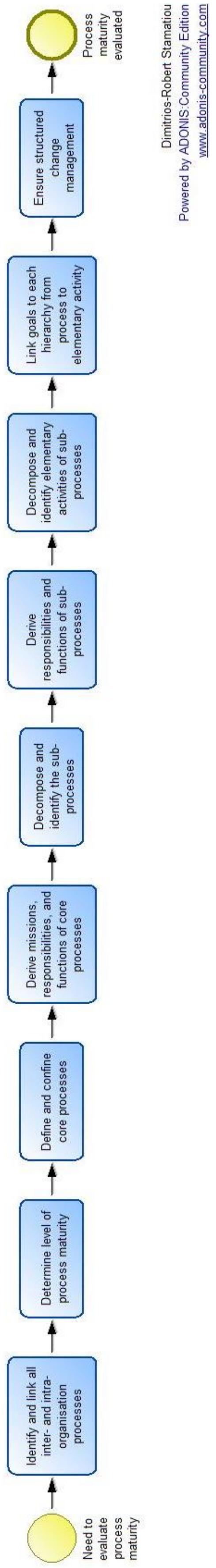
Διαγράμματα προς ανάλυση



Εικόνα 1



Εικόνα 2


Need to evaluate process maturity
Identify and link all inter- and intra-organisation processes
Determine level of process maturity
Define and confine core processes
Derive missions, responsibilities, and functions of core processes
Decompose and identify the sub-processes
Derive responsibilities and functions of sub-processes
Decompose and identify elementary activities of sub-processes
Link goals to each hierarchy from process to elementary activity
Ensure structured change management
Process maturity evaluated
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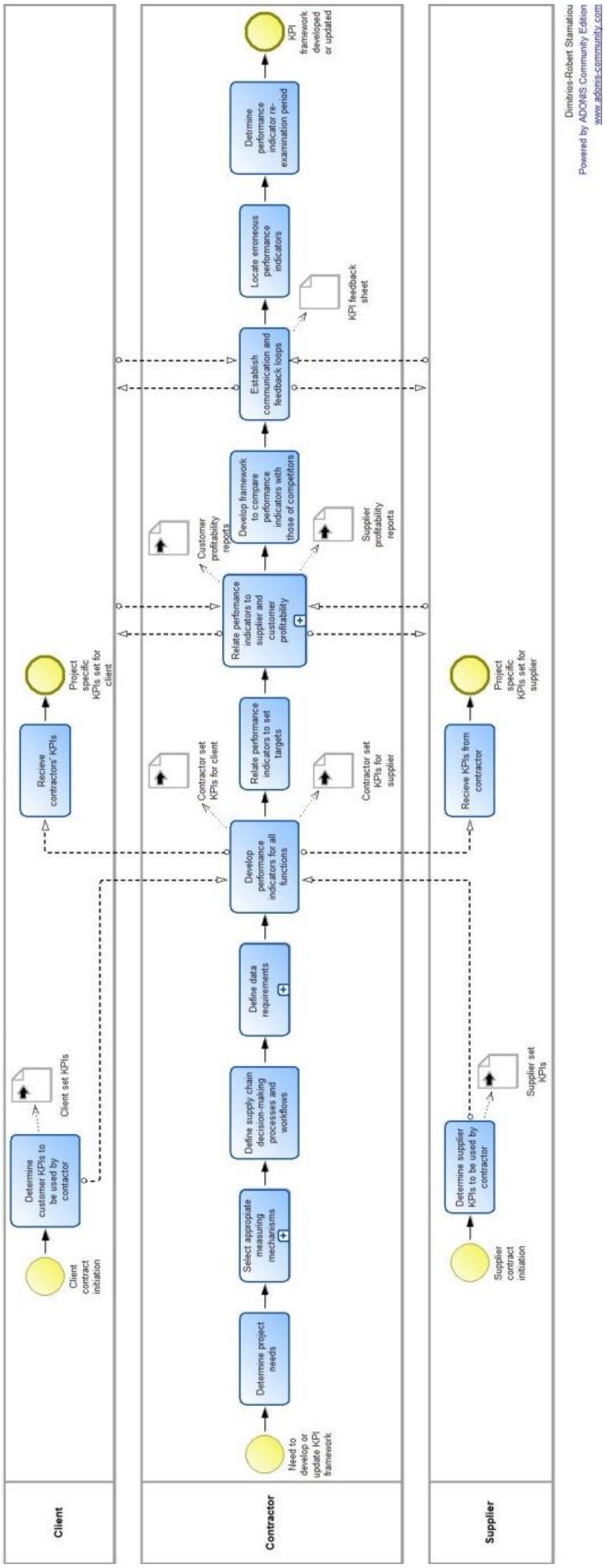
Εικόνα 3


Client
Contractor
Supplier
Client contract initiation
Determine customer KPIs to be used by contactor
Client set KPIs
Recieve contractors' KPIs
Project specific KPIs set for client
Need to develop or update KPI framework
Determine project needs
Select appropriate measuring mechanisms
Define supply chain decision-making processes and workflows
Define data requirements
Develop performance indicators for all functions
Contractor set KPIs for client
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Relate performance indicators to set targets
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Εικόνα 4

Ερωτηματολόγιο 2

Σκοπός συνέντευξης

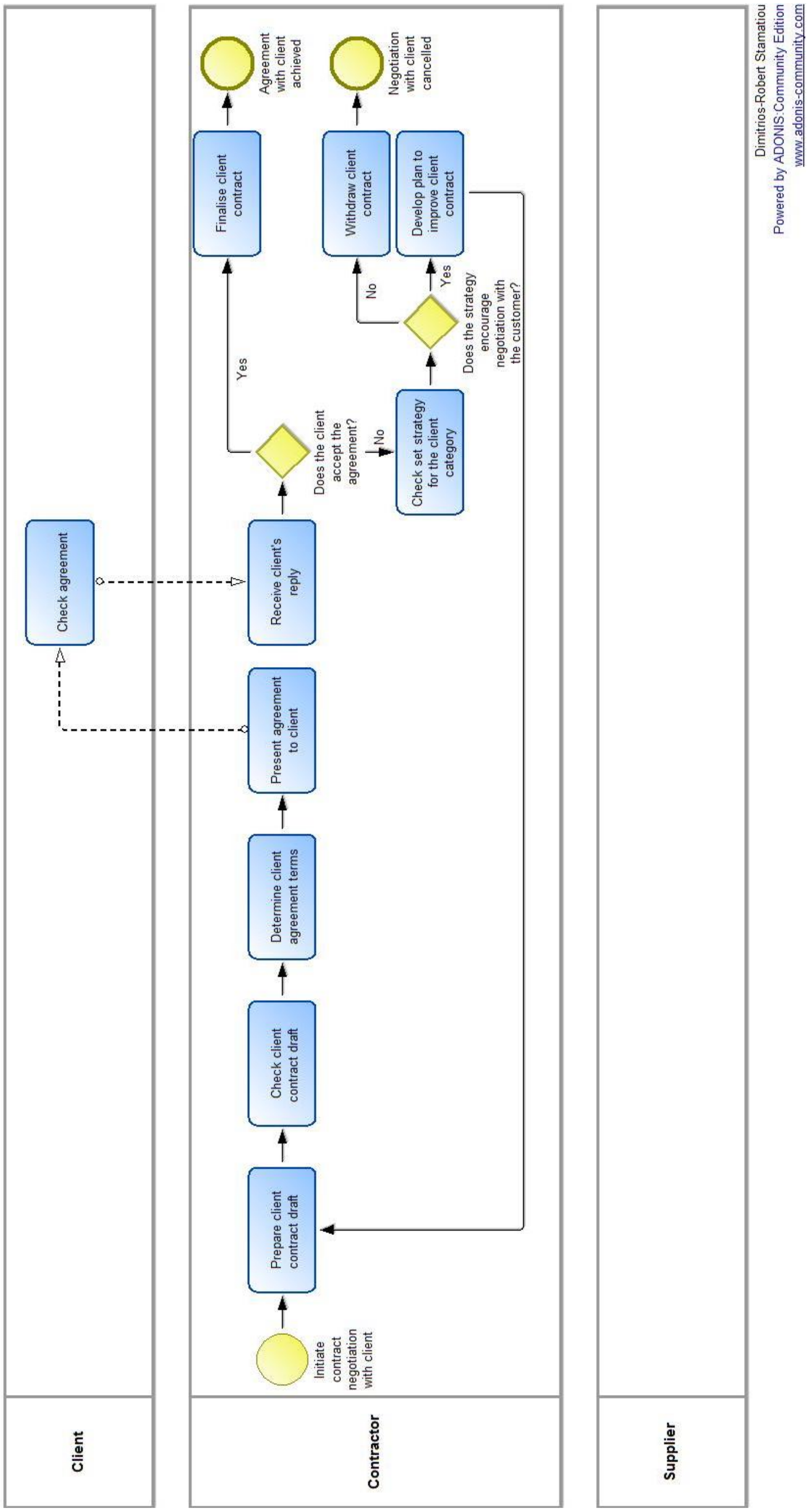
Η σύγχρονη τάση στη βιβλιογραφία των κατασκευών είναι η διοίκηση των κατασκευαστικών έργων μέσα από αρχές της θεωρίας των εφοδιαστικών αλυσίδων. Το έργο αντιμετωπίζεται ως προϊόν μιας πολύπλοκης παραγωγικής διαδικασίας στην οποία κεντρικό ρόλο αναλαμβάνει ο κύριος εργολάβος. Στο πλαίσιο της έρευνας για την παρούσα διδακτορική διατριβή, προσαρμόζεται μοντέλο αναφοράς διαδικασιών διοίκησης εφοδιαστικής αλυσίδας που αναπτύχθηκε για την παραγωγική βιομηχανία στις ανάγκες του κατασκευαστικού κλάδου. Στο μοντέλο αυτό η διαχείριση σχέσεων με πελάτες και η διαχείριση σχέσεων με προμηθευτές αντιμετωπίζονται ως οικογένειες διαδικασιών που επηρεάζουν την εφοδιαστική αλυσίδα του έργου. Προς το παρόν οι διαδικασίες του μοντέλου βασίζονται σε δεδομένα που έχουν συλλεχθεί μετά από ενδελεχή βιβλιογραφική έρευνα. Σκοπός της συνέντευξης είναι η συλλογή δεδομένων για τις παραπάνω διαδικασίες στην πραγματική ζωή και η σύγκριση των δεδομένων αυτών με τα βιβλιογραφικά δεδομένα. Τα αποτελέσματα της σύγκρισης χρησιμεύουν για: 1) επιβεβαίωση των δεδομένων που συλλέχθηκαν από τη βιβλιογραφία, 2) περεταίρω/ βαθύτερη ανάλυση των διαδικασιών που έχουν δημιουργηθεί και 3) καταγραφή βέλτιστων πρακτικών που δεν υπάρχουν στη βιβλιογραφία.

Ερωτήσεις

1) Οι κατασκευαστικές εταιρείες κατηγοριοποιούν τους πελάτες τους; Με βάση ποια κριτήρια γίνεται αυτή η κατηγοριοποίηση; Υπάρχουν ομάδες εντός της εταιρείας που διαχειρίζονται ομάδες πελατών ανάλογα με την κατηγοριοποίηση αυτών;
2) Οι κατασκευαστικές διατηρούν ιστορικό για κάθε πελάτη; Ελέγχεται το ιστορικό των πελατών πριν η κατασκευαστική εισέλθει στον διαγωνισμό για την εργολαβία; Ελέγχονται οι λογαριασμοί των πελατών για αναγνώριση ενδεχόμενης στενότερης συνεργασίας;
3) Ποια είναι μια τυπική διαδικασία διαπραγμάτευσης σύμβασης με τους πελάτες (Εικόνα 1); Οι συμβάσεις ενημερώνονται κατά τη διάρκεια του έργου σε περίπτωση που εμφανιστούν προβλήματα; Οι προμηθευτές μπορούν να επέμβουν στις διαπραγματεύσεις με τους πελάτες;
4) Υπάρχει κάποιο τμήμα «εξυπηρέτησης πελατών» το οποίο διαχειρίζεται διάφορα συμβάντα κατά τη διάρκεια της κατασκευής, όπως αξιώσεις και αλλαγές στο έργο, ή μετά την ολοκλήρωση του έργου σε περίπτωση που προβλέπεται από τη σύμβαση (πχ συντήρηση);
5) Οι κατασκευαστικές εταιρείες κατηγοριοποιούν τους προμηθευτές τους; Με βάση ποια κριτήρια γίνεται αυτή η κατηγοριοποίηση; Υπάρχουν ομάδες εντός της εταιρείας που διαχειρίζονται ομάδες προμηθευτών ανάλογα με την κατηγοριοποίηση αυτών;
6) Οι κατασκευαστικές διατηρούν ιστορικό για κάθε προμηθευτή; Ελέγχεται το ιστορικό των προμηθευτών πριν τους ανατεθεί εργολαβία; Ελέγχονται οι λογαριασμοί των προμηθευτών για αναγνώριση ενδεχόμενης στενότερης συνεργασίας;
7) Ποια είναι μια τυπική διαδικασία διαπραγμάτευσης σύμβασης με τους προμηθευτές (Εικόνα 2); Οι συμβάσεις ενημερώνονται κατά τη διάρκεια του έργου σε περίπτωση που εμφανιστούν προβλήματα; Οι πελάτες μπορούν να επέμβουν στις διαπραγματεύσεις με τους προμηθευτές;
8) Οι διαδικασίες διαχείρισης πελατών και προμηθευτών παρακολουθούνται με δείκτες απόδοσης; Η αντίστοιχη κερδοφορία/ζημία που επιφέρει η επιλογή του κάθε πελάτη ή προμηθευτή μετριέται;

Εκτιμώμενη διάρκεια
50-60 λεπτά

Διαγράμματα προς ανάλυση


Client
Contractor
Supplier
Initiate contract negotiation with client
Prepare client contract draft
Check client contract draft
Determine client agreement terms
Present agreement to client
Check agreement
Receive client's reply
Does the client accept the agreement?
Yes
No
Finalise client contract
Agreement with client achieved
Check set strategy for the client category
Does the strategy encourage negotiation with the customer?
No
Yes
Withdraw client contract
Negotiation with client cancelled
Develop plan to improve client contract
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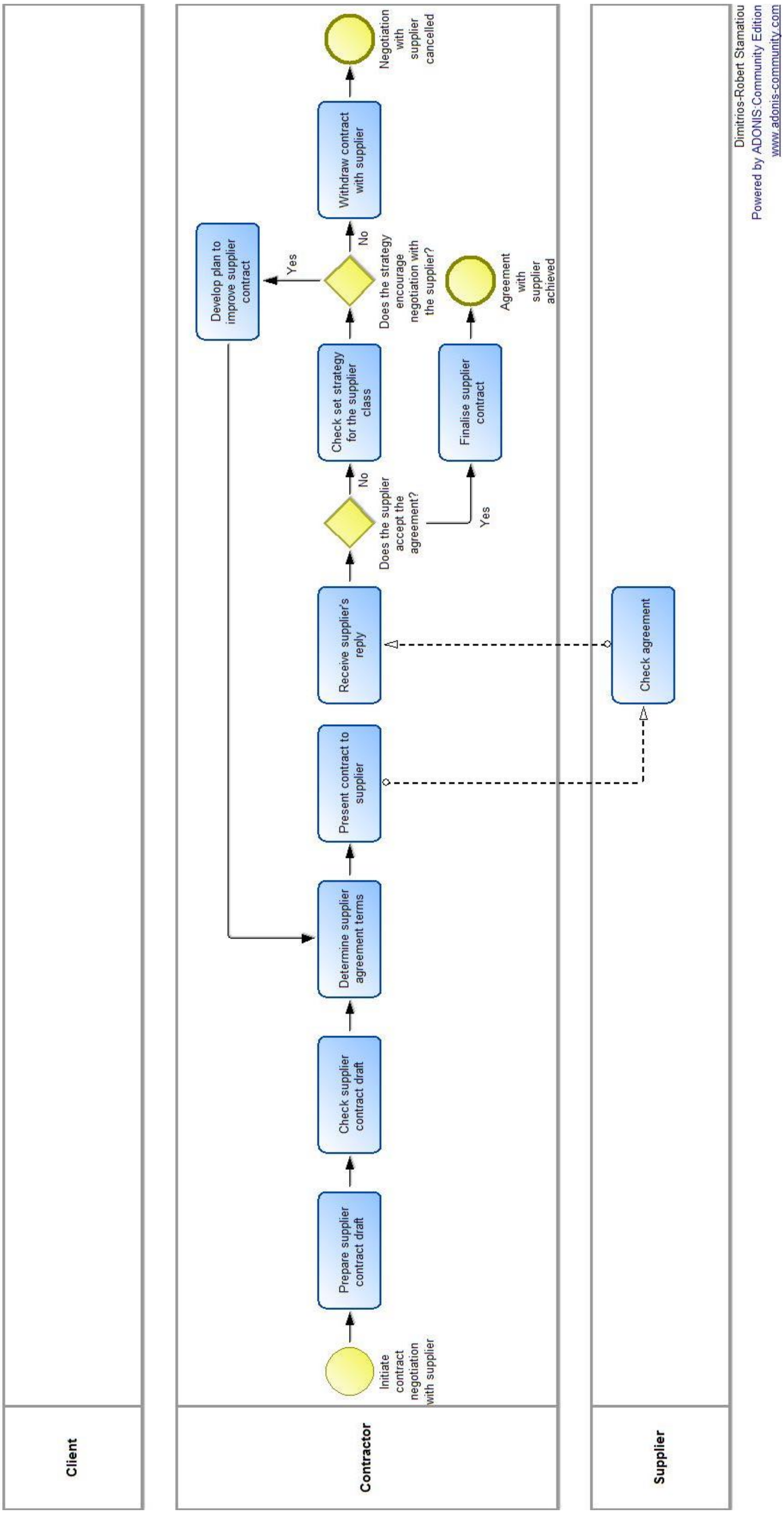
Εικόνα 1


Client
Contractor
Supplier
Initiate contract negotiation with supplier
Prepare supplier contract draft
Check supplier contract draft
Determine supplier agreement terms
Present contract to supplier
Receive supplier's reply
Does the supplier accept the agreement?
Yes
No
Finalise supplier contract
Agreement with supplier achieved
Check set strategy for the supplier class
Does the strategy encourage negotiation with the supplier?
Yes
No
Develop plan to improve supplier contract
Withdraw contract with supplier
Negotiation with supplier cancelled
Check agreement
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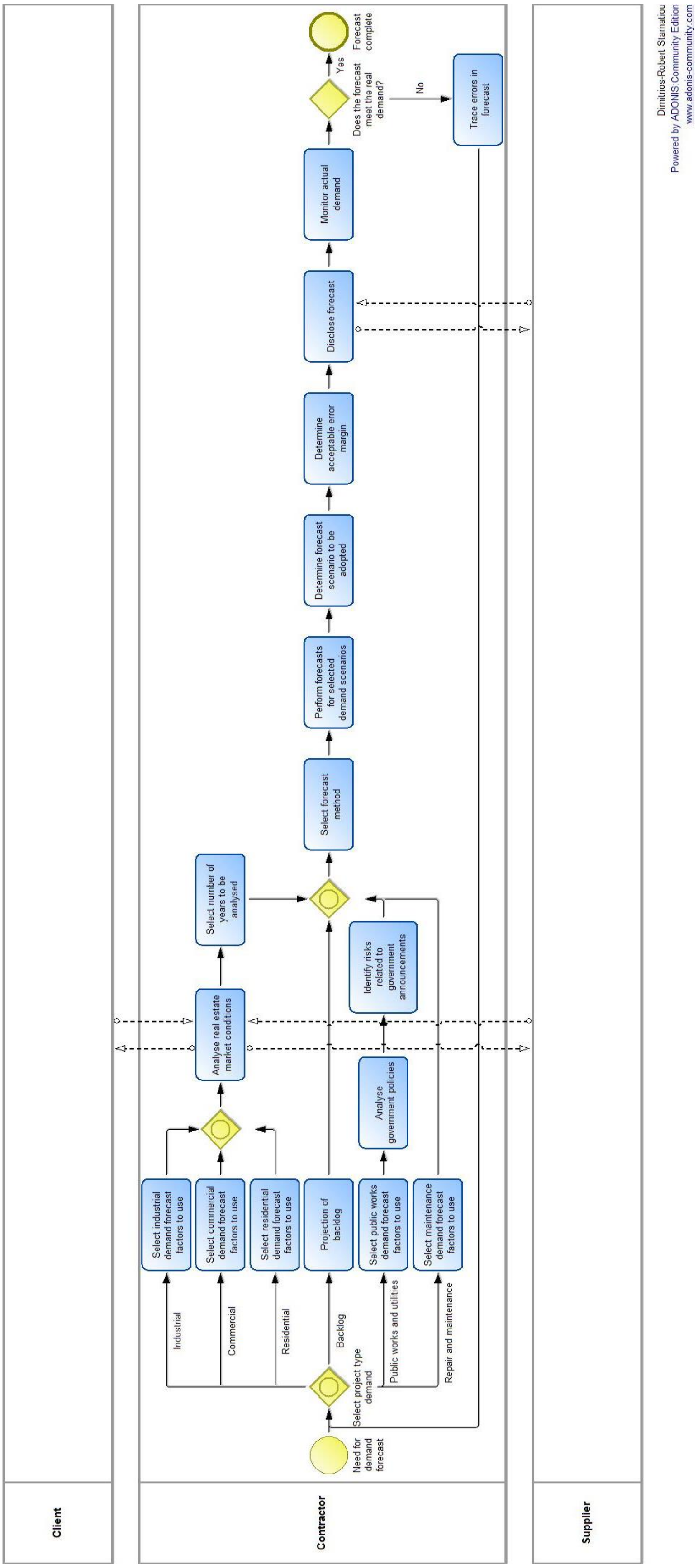
Εικόνα 2

Ερωτηματολόγιο 3
Σκοπός συνέντευξης
Η σύγχρονη τάση στη βιβλιογραφία των κατασκευών είναι η διοίκηση των κατασκευαστικών έργων μέσα από αρχές της θεωρίας των εφοδιαστικών αλυσίδων. Το έργο αντιμετωπίζεται ως προϊόν μιας πολύπλοκης παραγωγικής διαδικασίας στην οποία κεντρικό ρόλο αναλαμβάνει ο κύριος εργολάβος. Στο πλαίσιο της έρευνας για την παρούσα διδακτορική διατριβή, προσαρμόζεται μοντέλο αναφοράς διαδικασιών διοίκησης εφοδιαστικής αλυσίδας που αναπτύχθηκε για την παραγωγική βιομηχανία στις ανάγκες του κατασκευαστικού κλάδου. Στο μοντέλο αυτό η διαχείριση της ζήτησης και η ανάπτυξη νέων έργων αντιμετωπίζονται ως οικογένειες διαδικασιών που επηρεάζουν την εφοδιαστική αλυσίδα του έργου. Προς το παρόν οι διαδικασίες του μοντέλου βασίζονται σε δεδομένα που έχουν συλλεχθεί μετά από ενδελεχή βιβλιογραφική έρευνα. Σκοπός της συνέντευξης είναι η συλλογή δεδομένων για τις παραπάνω διαδικασίες στην πραγματική ζωή και η σύγκριση των δεδομένων αυτών με τα βιβλιογραφικά δεδομένα. Τα αποτελέσματα της σύγκρισης χρησιμεύουν για: 1) επιβεβαίωση των δεδομένων που συλλέχθηκαν από τη βιβλιογραφία, 2) περεταίρω/ βαθύτερη ανάλυση των διαδικασιών που έχουν δημιουργηθεί και 3) καταγραφή βέλτιστων πρακτικών που δεν υπάρχουν στη βιβλιογραφία.

Ερωτήσεις
1) Μπορούμε να επιβεβαιώσουμε ότι η διαχείριση της ζήτησης είναι μια λειτουργία των κατασκευαστικών εταιρειών;
2) Ποιες είναι οι πηγές συλλογής δεδομένων για τη ζήτηση;
3) Ποια είναι μια τυπική διαδικασία πρόγνωσης της ζήτησης (Εικόνα 1);
4) Οι κατασκευαστικές εταιρείες έχουν ανάγκη από τη μείωση της μεταβλητότητας της ζήτησης ή την αύξηση της ευελιξίας τους; Πόσο αντιπροσωπευτική μιας τέτοιας διαδικασίας είναι η Εικόνα 2;
5) Μπορούμε να επιβεβαιώσουμε ότι η ανάπτυξη νέων έργων (κατασκευής) είναι μια σημαντική λειτουργία της εφοδιαστικής αλυσίδας των κατασκευαστικών έργων;
6) Ποιες είναι οι πηγές των νέων έργων;
7) Ποια είναι μια τυπική διαδικασία καθορισμού και αξιολόγησης νέων έργων (Εικόνα 3);
8) Εξετάζονται οι επιπτώσεις της ανάπτυξης νέων έργων στο προσωπικό της εταιρείας;
9) Ποια είναι μια τυπική διαδικασία ανάπτυξης νέου έργου (Εικόνα 4);
10) Πως λαμβάνεται μια απόφαση για υπεργολαβία κατά τη φάση της ανάπτυξης;
11) Πόσο συμβάλουν τα πληροφοριακά συστήματα BIM (Building Information Modelling) στην ανάπτυξη νέων έργων; Πιστεύετε ότι η πρόσβαση των υπεργολάβων σε τέτοια συστήματα προσφέρει πλεονεκτήματα στον συντονισμό των διαδικασιών;
12) Η απόδοση των διαδικασιών παρακολουθείται με δείκτες απόδοσης;

Εκτιμώμενη διάρκεια
50-60 λεπτά

Διαγράμματα προς ανάλυση


Client
Contractor
Supplier
Need for demand forecast
Select project type demand
Industrial
Commercial
Residential
Backlog
Public works and utilities
Repair and maintenance
Select industrial demand forecast factors to use
Select commercial demand forecast factors to use
Select residential demand forecast factors to use
Projection of backlog
Select public works demand forecast factors to use
Select maintenance demand forecast factors to use
Analyse government policies
Analyse real estate market conditions
Identify risks related to government announcements
Select number of years to be analysed
Select forecast method
Perform forecasts for selected demand scenarios
Determine forecast scenario to be adopted
Determine acceptable error margin
Disclose forecast
Monitor actual demand
Does the forecast meet the real demand?
Yes
No
Forecast complete
Trace errors in forecast
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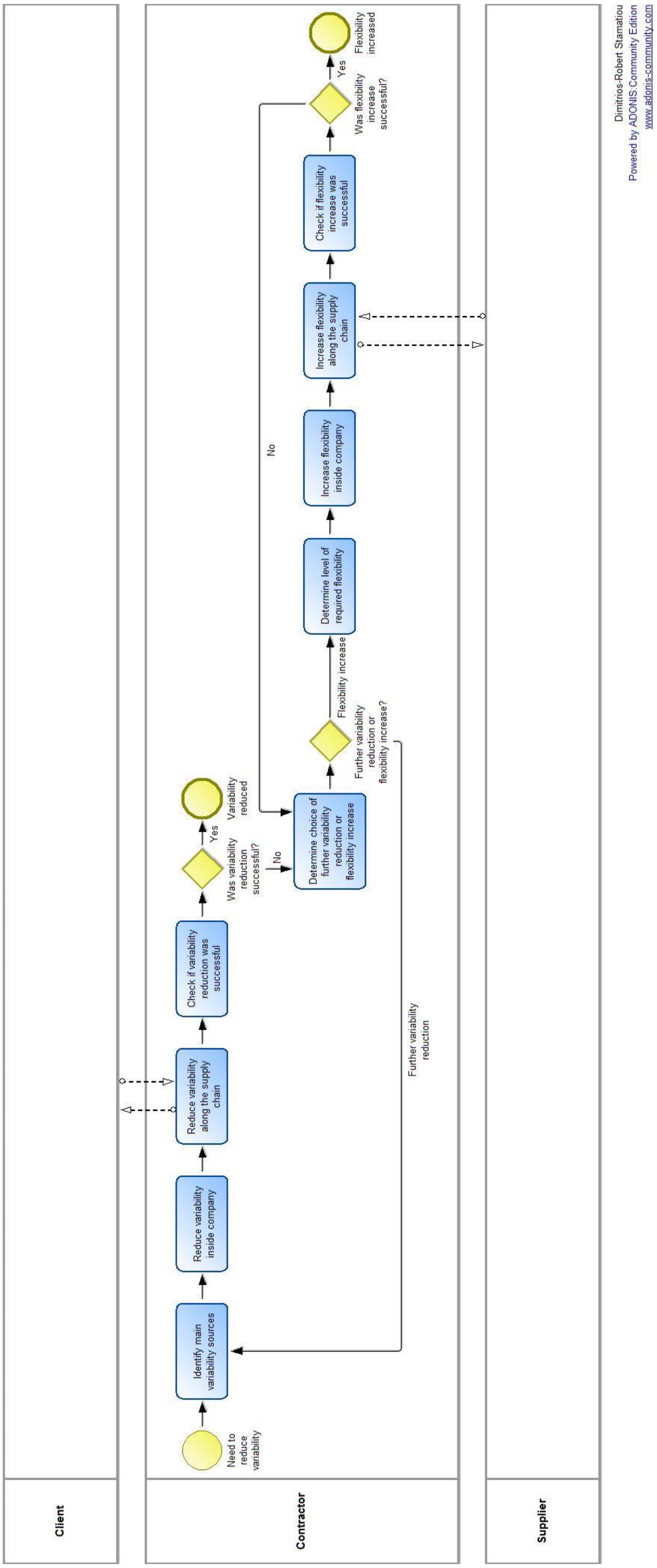
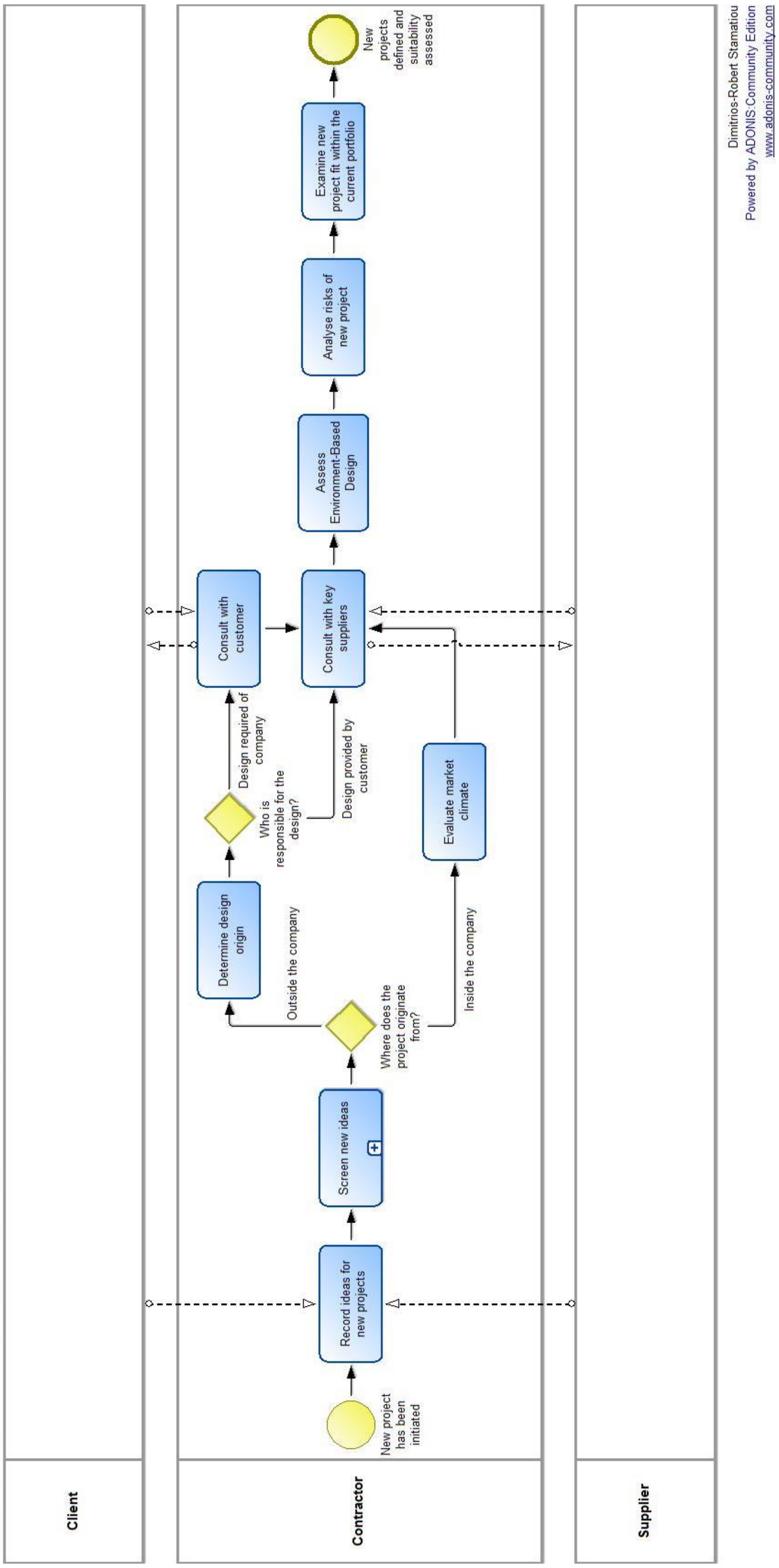
Εικόνα 1

Development of a process reference model for construction supply chains: the contractor's view



Εικόνα 2


Client
Contractor
Supplier
New project has been initiated
Record ideas for new projects
Screen new ideas
Where does the project originate from?
Outside the company
Inside the company
Determine design origin
Who is responsible for the design?
Design required of company
Design provided by customer
Evaluate market climate
Consult with customer
Consult with key suppliers
Assess Environment-Based Design
Analyse risks of new project
Examine new project fit within the current portfolio
New projects defined and suitability assessed
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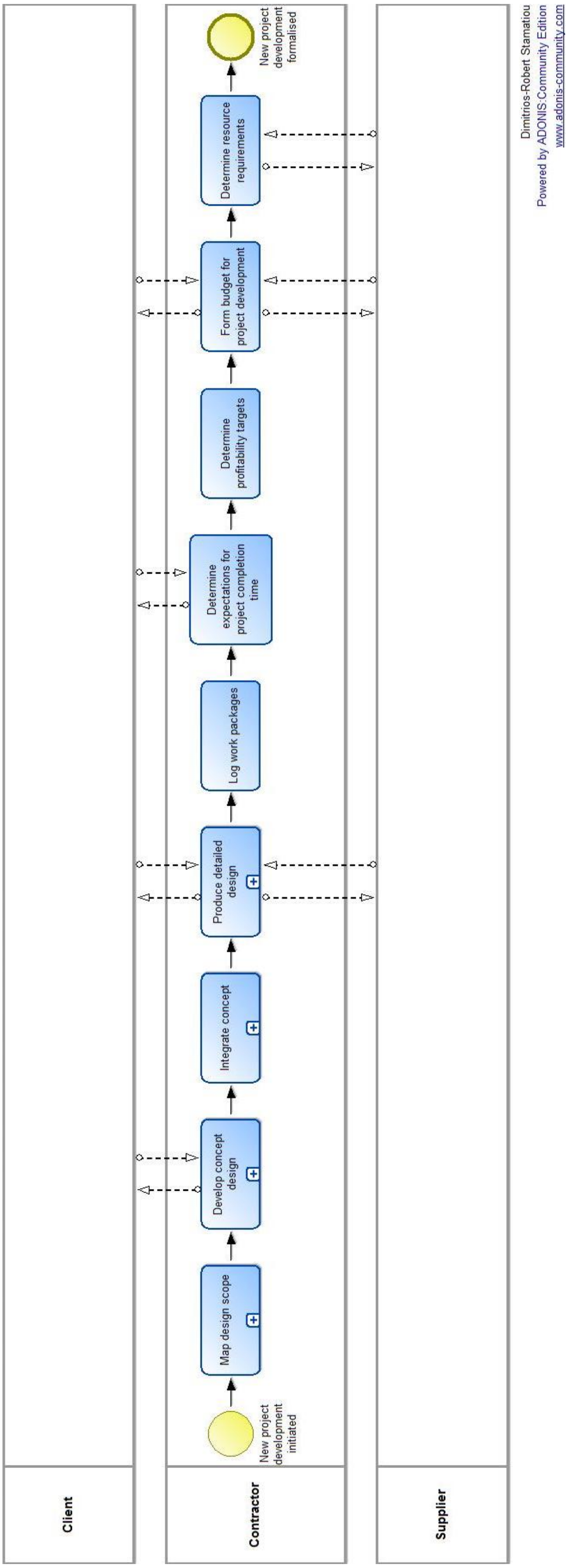
Εικόνα 3

Development of a process reference model for construction supply chains:
the contractor's view



Εικόνα 4

Ερωτηματολόγιο 4

Σκοπός συνέντευξης

Η σύγχρονη τάση στη βιβλιογραφία των κατασκευών είναι η διοίκηση των κατασκευαστικών έργων μέσα από αρχές της θεωρίας των εφοδιαστικών αλυσίδων. Το έργο αντιμετωπίζεται ως προϊόν μιας πολύπλοκης παραγωγικής διαδικασίας στην οποία κεντρικό ρόλο αναλαμβάνει ο κύριος εργολάβος. Στο πλαίσιο της έρευνας για την παρούσα διδακτορική διατριβή, προσαρμόζεται μοντέλο αναφοράς διαδικασιών διοίκησης εφοδιαστικής αλυσίδας που αναπτύχθηκε για την παραγωγική βιομηχανία στις ανάγκες του κατασκευαστικού κλάδου. Στο μοντέλο αυτό η διαχείριση πακέτων εργασίας και η διαχείριση ροής παραγωγής (κατασκευής) αντιμετωπίζονται ως οικογένειες διαδικασιών που επηρεάζουν την εφοδιαστική αλυσίδα του έργου. Προς το παρόν οι διαδικασίες του μοντέλου βασίζονται σε δεδομένα που έχουν συλλεχθεί μετά από ενδελεχή βιβλιογραφική έρευνα. Σκοπός της συνέντευξης είναι η συλλογή δεδομένων για τις παραπάνω στην πραγματική ζωή και η σύγκριση των δεδομένων αυτών με τα βιβλιογραφικά δεδομένα. Τα αποτελέσματα της σύγκρισης χρησιμεύουν για: 1) επιβεβαίωση των δεδομένων που συλλέχθηκαν από τη βιβλιογραφία, 2) περεταίρω/ βαθύτερη ανάλυση των διαδικασιών που έχουν δημιουργηθεί και 3) καταγραφή βέλτιστων πρακτικών που δεν υπάρχουν στη βιβλιογραφία.

Ερωτήσεις

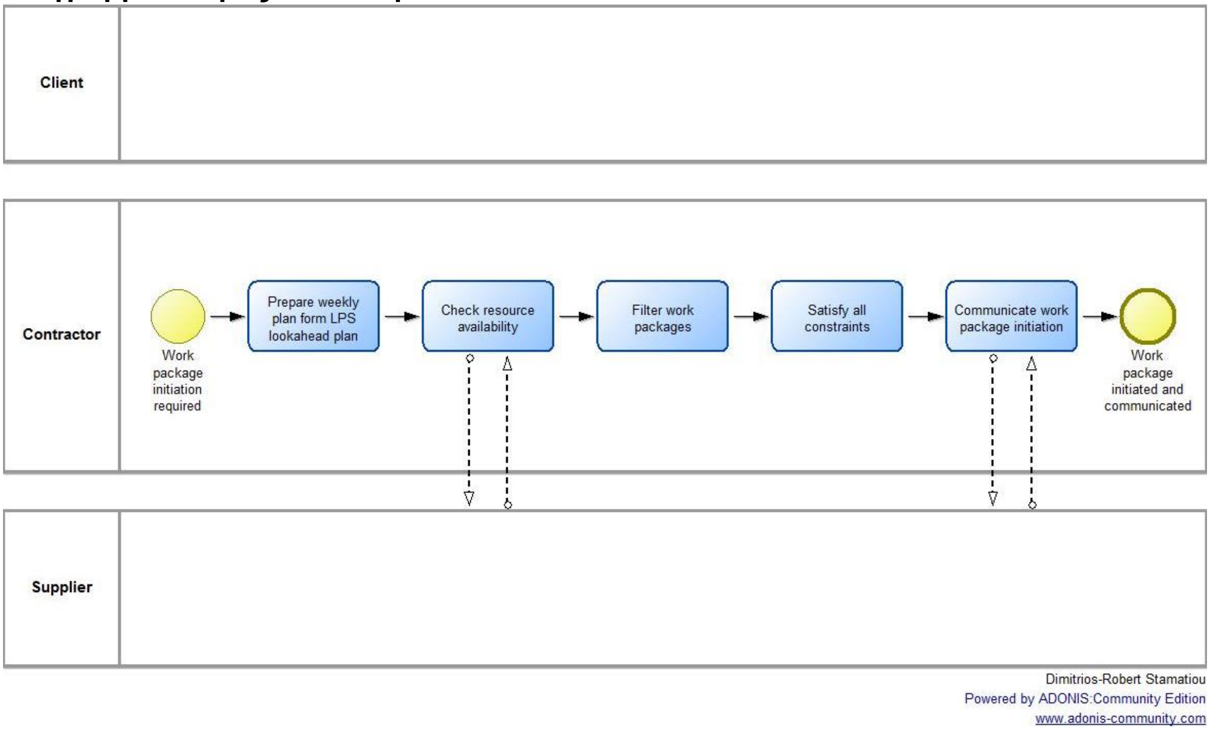
1) Μπορούμε να επιβεβαιώσουμε ότι η διαχείριση πακέτων εργασίας είναι μια λειτουργία που διαχειρίζεται τη ροή πληροφορίας κατά μήκος της εφοδιαστικής αλυσίδας;
2) Ποια είναι μια τυπική διαδικασία προετοιμασίας πακέτων εργασίας προς εκτέλεση (Εικόνα 1);
3) Ποια είναι μια τυπική διαδικασία παρακολούθησης εκτελούμενων πακέτων εργασίας (Εικόνα 2);
4) Ποια είναι μια τυπική διαδικασία διαχείρισης εγγράφων και ποια έγγραφα περιέχει ένα πακέτο εργασίας (Εικόνα 3);
5) Μπορούμε να επιβεβαιώσουμε ότι η διαχείριση ροής παραγωγής (κατασκευής) είναι μια λειτουργία που διαχειρίζεται τη ροή πόρων κατά μήκος της εφοδιαστικής αλυσίδας;
6) Ποια είναι μια τυπική διαδικασία μακροπρόθεσμου σχεδιασμού εκτέλεσης εργασιών και προγραμματισμού πόρων (Εικόνα 4);
7) Ποια είναι μια τυπική διαδικασία βραχυπρόθεσμου σχεδιασμού εκτέλεσης εργασιών και διαχείρισης πόρων (Εικόνα 5);
8) Ποια είναι μια τυπική διαδικασία παρακολούθησης εκτελούμενων εργασιών (Εικόνα 6);
9) Ποια είναι τα συχνότερα προβλήματα που εμφανίζονται στη διαχείριση πακέτων εργασίας;
10) Πόσο μεγάλο πρόβλημα αποτελεί η έλλειψη χώρου στην οικοδομή και κατά πόσο επηρεάζεται το κόστος του έργου από την έλλειψη προγραμματισμού; Πόσο εφικτή είναι η λύση των κέντρων διανομής (λειτουργεί ως αποθήκη) για την αντιμετώπιση αυτών των προβλημάτων;
11) Πόσο συμβάλουν τα πληροφοριακά συστήματα BIM (Building Information Modelling) στη διαχείριση των πακέτων εργασίας και της ροής παραγωγής (κατασκευής); Πιστεύετε ότι η πρόσβαση των υπεργολάβων σε τέτοια συστήματα προσφέρει πλεονεκτήματα στον συντονισμό των διαδικασιών;
12) Η απόδοση των διαδικασιών παρακολουθείται με δείκτες απόδοσης;

Development of a process reference model for construction supply chains: the contractor's view

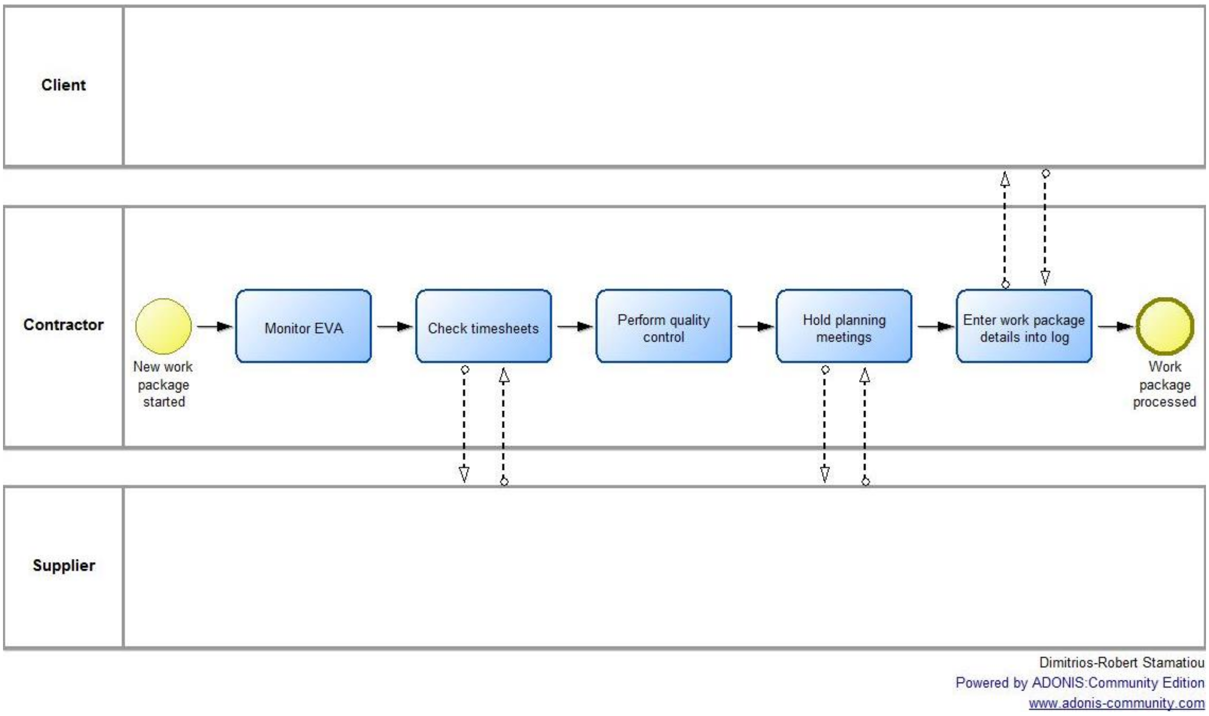
Εκτιμώμενη διάρκεια

60-70 λεπτά

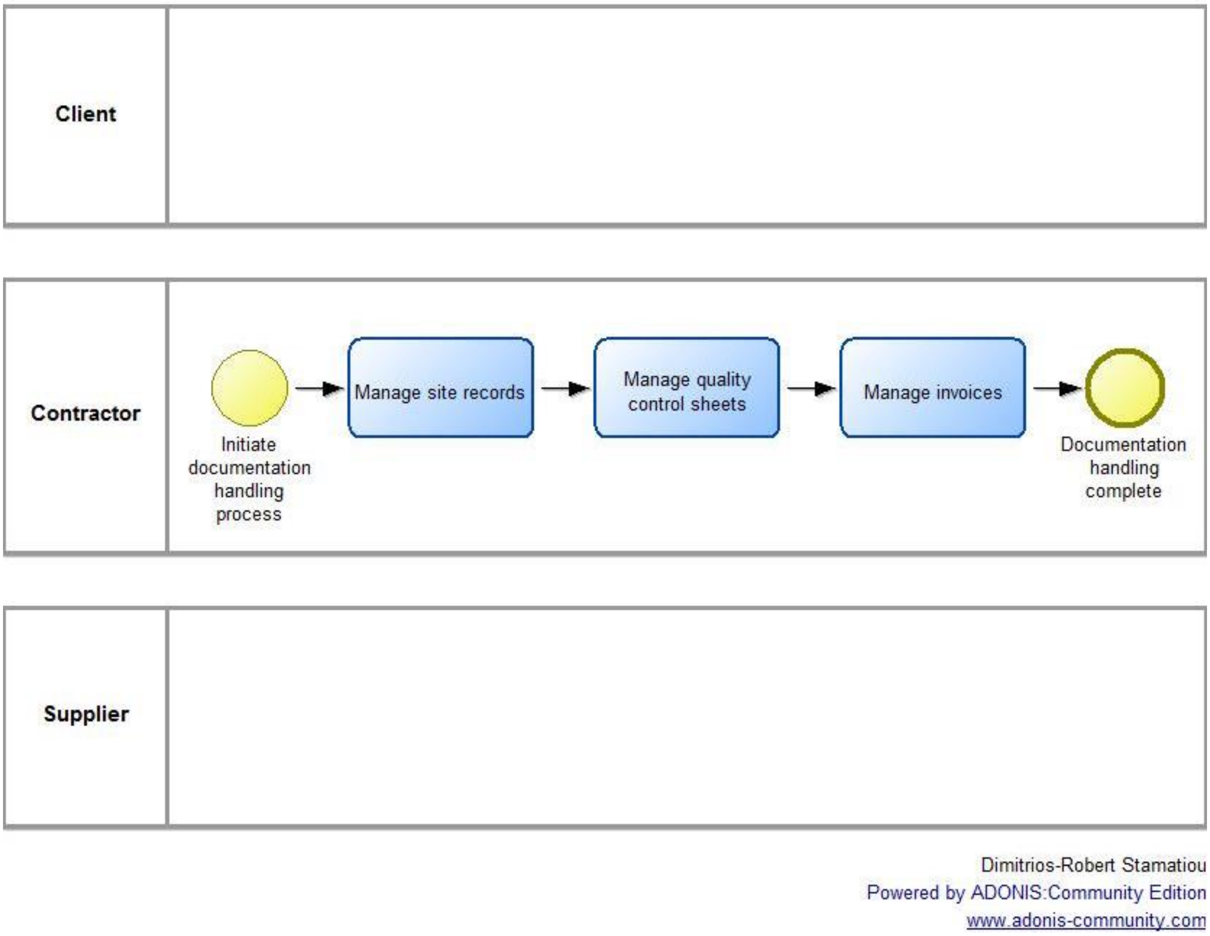
Διαγράμματα προς ανάλυση



Εικόνα 1



Εικόνα 2


Client
Contractor
Manage site records
Manage quality control sheets
Manage invoices
Initiate documentation handling process
Documentation handling complete
Supplier
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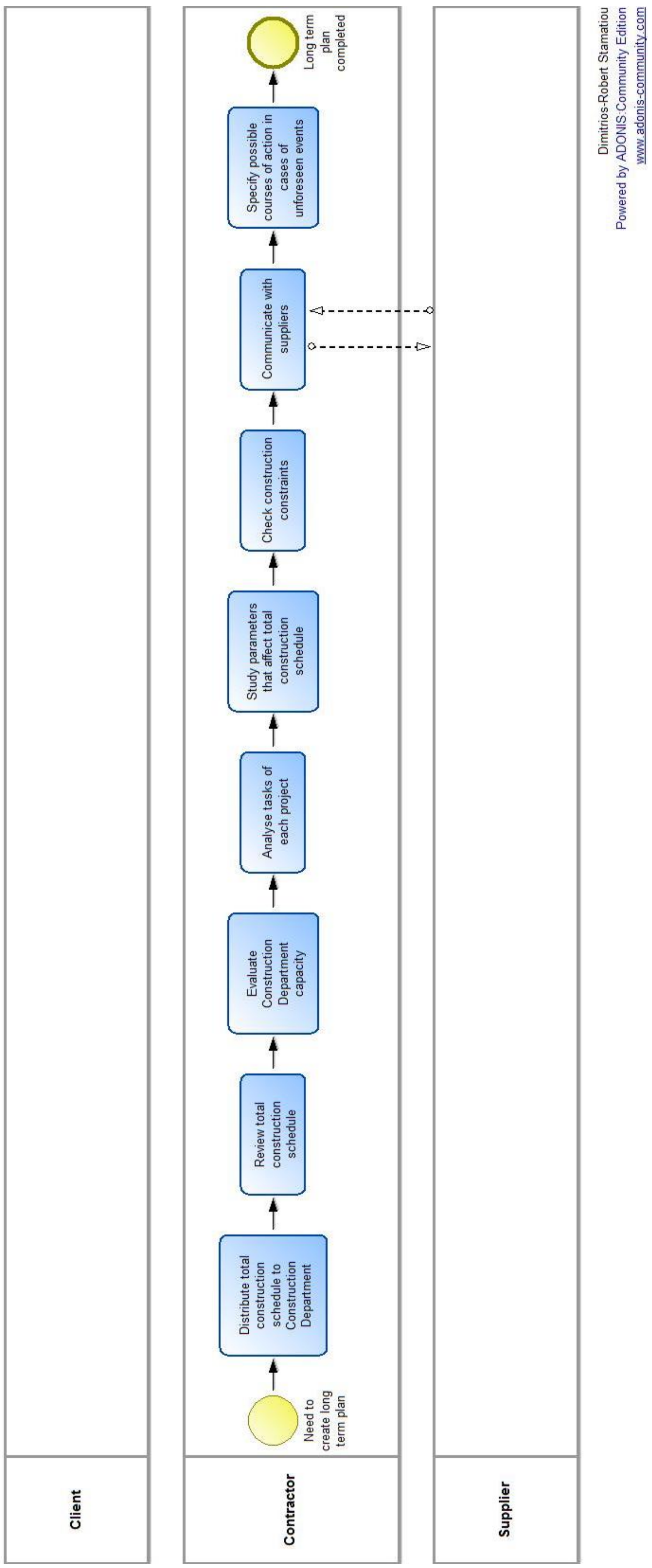
Εικόνα 3


Client
Contractor
Supplier
Need to create long term plan
Distribute total construction schedule to Construction Department
Review total construction schedule
Evaluate Construction Department capacity
Analyse tasks of each project
Study parameters that affect total construction schedule
Check construction constraints
Communicate with suppliers
Specify possible courses of action in cases of unforeseen events
Long term plan completed
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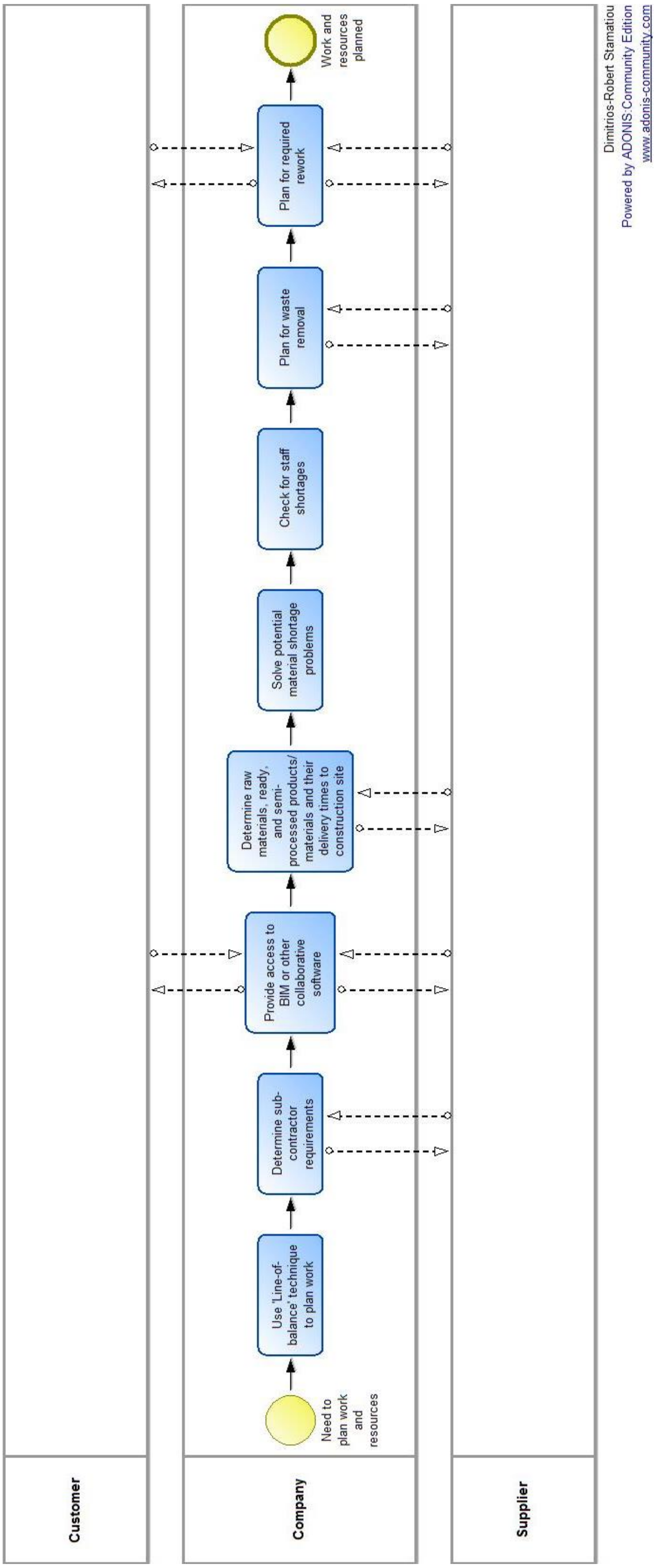
Εικόνα 4


Customer
Company
Supplier
Need to plan work and resources
Use 'Line-of-balance' technique to plan work
Determine sub-contractor requirements
Provide access to BIM or other collaborative software
Determine raw materials, ready, and semi-processed products/ materials and their delivery times to construction site
Solve potential material shortage problems
Check for staff shortages
Plan for waste removal
Plan for required rework
Work and resources planned
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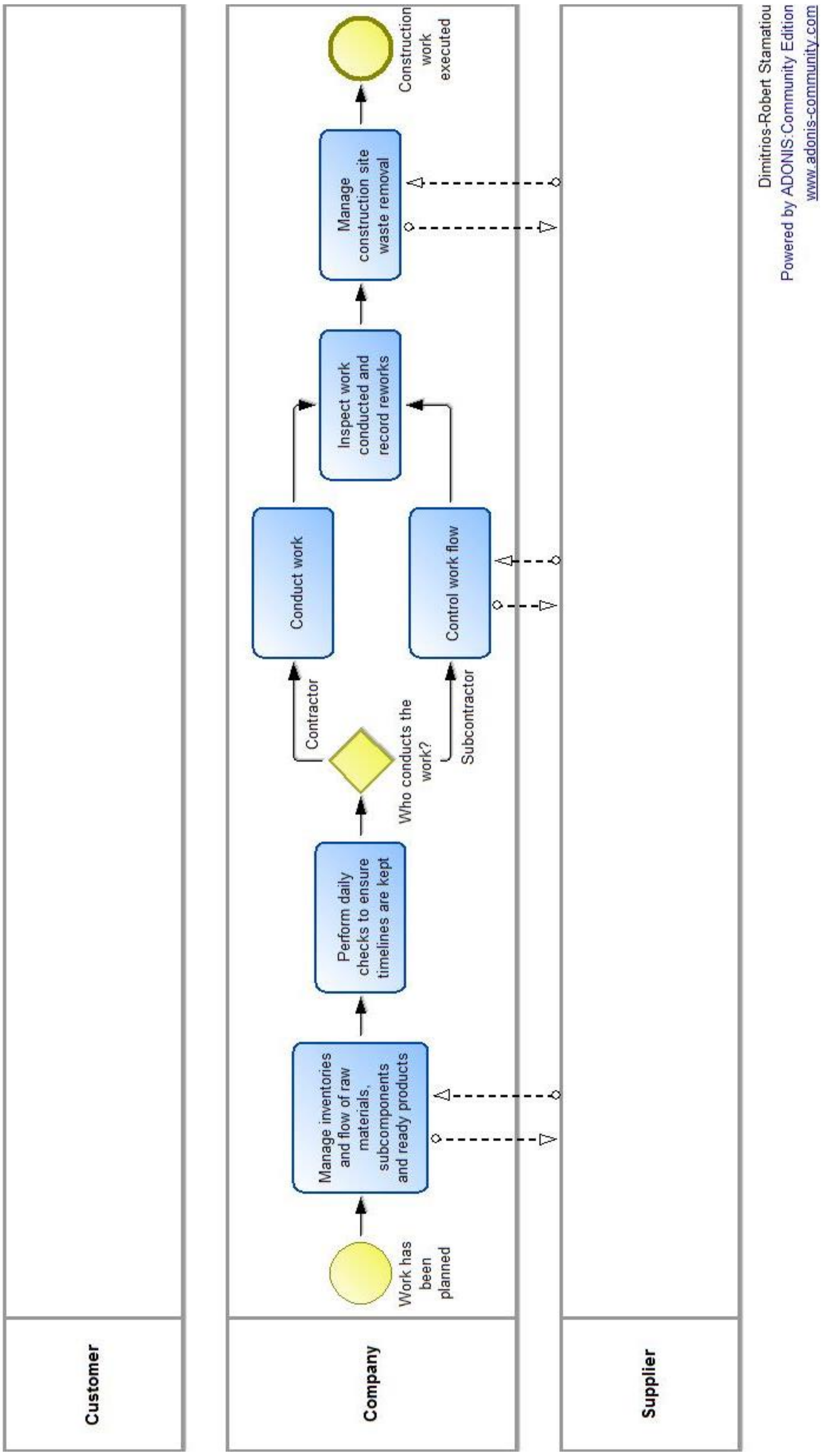
Εικόνα 5


Customer
Company
Supplier
Work has been planned
Manage inventories and flow of raw materials, subcomponents and ready products
Perform daily checks to ensure timelines are kept
Who conducts the work?
Contractor
Subcontractor
Conduct work
Control work flow
Inspect work conducted and record reworks
Manage construction site waste removal
Construction work executed
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Εικόνα 6

Ερωτηματολόγιο 5

Σκοπός συνέντευξης

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Ερωτήσεις

15) Ποια είναι μια τυπική διαδικασία αξιώσεων (claims);
16) Πως αναγνωρίζετε μία αξίωση;
17) Υπάρχουν καταγεγραμμένες οδηγίες για το χειρισμό των αξιώσεων που δυνητικά θα εμφανιστούν;
18) Μελετάται το ενδεχόμενο η αξίωση να έχει και μακροχρόνιες επιπτώσεις στο έργο;
19) Μπορείτε να περιγράψετε την τυπική τεκμηρίωση μιας αξίωσης (τι είδους έγγραφα);
20) Εκτός από χρόνο ή/και χρήματα με τι άλλο μπορεί να αποζημιωθεί μία αξίωση;
21) Ποια είναι η διαδικασία προετοιμασίας για τη διαπραγμάτευση;
22) Ποια είναι μία τυπική διαδικασία ακύρωσης συμβάσεων;
23) Παρακολουθείτε τη διαδικασία των αξιώσεων με τη χρήση δεικτών απόδοσης; Ναι ή όχι και γιατί; Αν ναι, πώς;
24) Πόσο συχνά εμφανίζονται αξιώσεις σε έργα;
25) Κατά τη γνώμη σας, πώς επηρεάζουν οι αξιώσεις την εφοδιαστική αλυσίδα ενός έργου;
26) Πιστεύετε ότι οι αξιώσεις βλάπτουν τις σχέσεις των συμμετεχόντων στο έργο;
27) Όσον αφορά τις αξιώσεις, η πείρα σας δείχνει ότι αντιμετωπίζονται με τον ίδιο τρόπο όλοι οι συμμετέχοντες ενός έργου ή υπάρχουν συμμετέχοντες που απολαμβάνουν προνόμια λόγω καλύτερης σχέσης με τον ανάδοχο του έργου;
28) Τι ποσοστό των αξιώσεων επιλύεται εξωδικαστικά και πόσες οδηγούνται στο δικαστήριο;

Εκτιμώμενη διάρκεια

60-70 λεπτά