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Διαμόρφωση Προδιαγραφών Πληροφοριακού Συστήματος Διατήρησης Δεδομένων Εγκαταστάσεων Πελατών, για τον Προγραμματισμό Εταιρείας Παραγωγής Συστημάτων Λιθογραφίας

Design Specifications of an Information System to Maintain Customer Site Infrastructure Information for Planning Purposes in a Manufacturing Company

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Οκτώβριος 2016

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ABSTRACT

In this research that has been conducted at COMPANY X, an information and communication solution is being investigated. This solution will be used for planning purposes. The lack of communication of the critical information has been defined and an analysis of the requirements for a solution has been developed. At the end, several system solutions have been presented and one is proposed as the most suitable for the current situation. Overall this project purpose was to demonstrate whether this problem COMPANY X is facing in its daily operations is significant enough, and what sort of possible solutions could solve it. Finally, based on this investigation COMPANY X employees are called upon to decide if this problem is a priority or not and deal with it accordingly.

Στην παρούσα εργασία διενεργείται μια έρευνα για ένα πληροφοριακό σύστημα το οποίο θα χρησιμοποιηθεί για λόγους προγραμματισμού εταιρείας παραγωγής συστημάτων λιθογραφίας. Προσδιορίζεται η έλλειψη επικοινωνίας της χρήσιμης πληροφορίας και πραγματοποιείται η ανάλυση των απαιτήσεων του συστήματος. Εν συνεχεία παρουσιάζονται πιθανές λύσεις, από τις οποίες επιλέγεται και προτείνεται η ιδανικότερη σε σύγκριση με τα δεδομένα του προβλήματος.

ACKNOWLEDGEMENTS

I would like to express my deep gratitude to Doctor Sotiris Gayialis, my supervisor from NTUA, for giving me the opportunity to work on such an interesting project. Also, I would like to convey my sincere appreciation for his patient guidance, his useful critique and valuable suggestions.

Furthermore, I would like to thank COMPANY X and specifically my mentor Eric Schmellekamp for trusting me and guiding through the long processes of COMPANY X.

Finally, I wish to thank my family and friends for their constant support and motivation throughout the project and especially at the very end when I needed it more.

EXECUTIVE SUMMARY

COMPANY X is a company that produces lithography systems. These systems perform the most critical step in the production of integrated circuits (also known as chips). The newest addition to the range of systems that COMPANY X produces is the MACHINE X system. The MACHINE X system can illuminate very accurately and therefore it can produce chips with extremely small details.

In order to achieve the highest possible availability, COMPANY X wants to improve the current way-of-working with regard to the MACHINE X machine. One of the changes that could possibly improve the availability is the way of acquiring, storing and communicating information from the customers' sites. This is important for COMPANY X in order to improve the planning of actions on the customer's machines, as well as to the future machine designs. This project's goal is to explore the possibility for a change and introduce a potential solution.

The projects overall comes down to three main objectives. The first one is to raise awareness about the specific issue that has been noticed by a few employees. Until recently that the main business focus was on the previous machineries, there was no need to focus on the environment of the machines at the customers sites. However, the new machine is way too complicated, which forces the process of improving its availability, to consider more multi aspects solutions. Nevertheless, people do not like changes unless they are necessary, and the aim of the project was to demonstrate why it is necessary to consider this issue as an important problem. In the third and fourth chapters the company's status quo is being depicted as well as the problem stated above.

The second objective of the project was to analyze the situation and come up with the requirements of the system to solve the problem. The analysis was made by investigating all the engaged parties and actions in the extent of my limited range, since almost all the processes that are discussed in this project take place all over the world and a massive number of people are involved. The analysis had to be narrowed to the processes that are mostly affected and the requirements as well as the solutions were focused on those. Throughout the fifth chapter the analysis of the requirements is taking place and the requirements identified are presented.

The third objective was to investigate an ICT solution that could fulfill the requirements and at the same time could fit in the organization's current configurations. This investigation is being presented throughout the chapters 6 to 8 were the results are compared and a final solution is selected.

ΠΕΡΙΛΗΨΗ

Η παρούσα εργασία πραγματοποιήθηκε στην εταιρεία COMPANY X. Το καθεστώς στην οποία εκπονήθηκε ήταν εξάμηνη πρακτική, κατόπιν χρηματοδότησης από την Erasmus Placement.

Η εν λόγω εταιρεία δραστηριοποιείται στην αγορά της παραγωγής ολοκληρωμένων κυκλωμάτων (integrated circuits – "chips") και εδρεύει λίγο έξω από το Αϊντχόφεν της Ολλανδίας. Παράγει μηχανήματα τα οποία χρησιμοποιούνται για την εκτύπωση μοτίβων ολοκληρωμένων κυκλωμάτων πάνω στους δίσκους σιλικόνης, που είναι και το πιο κρίσιμο στάδιο στη παραγωγή τους. Η τελευταία προσθήκη στη φαρέτρα των μηχανημάτων που παράγει η COMPANY X είναι τα συστήματα MACHINE X. Αυτά τα συστήματα χρησιμοποιούν ακραία υπεριώδη φωτοβολία, για να εκτυπώνουν με εξαιρετικά μικρή λεπτομέρεια.

Για να αυξήσει την παραγωγικότητα αυτών των μηχανημάτων στο πελάτη, η COMPANY X αποφάσισε να αναθεωρήσει τον υφιστάμενο τρόπο λειτουργίας της εταιρείας σε σχέση με τα μηχανήματα αυτά. Ένας από τους πιθανούς τρόπους να αυξηθεί η παραγωγικότητα, είναι η βελτίωση των μηχανισμών ανάκτησης, αποθήκευσης και μετάδοσης της πληροφορίας από το περιβάλλον των μηχανημάτων στις εγκαταστάσεις των πελατών. Αυτή η πληροφορία είναι σημαντική για την εταιρεία, ώστε να βελτιώσει τον σχεδιασμό των δράσεων της στα μηχανήματα των εκάστοτε πελατών, αλλά και σε επίπεδο έρευνας και ανάπτυξης των επόμενων μοντέλων του μηχανήματος. Ο στόχος της παρούσης εργασίας είναι η εξερεύνηση της πιθανότητας για αλλαγή της υπάρχουσας μεθόδου, καθώς και τη σύσταση μιας ενδεχόμενης λύσης.

Η εργασία συνολικά έχει τρεις κυρίως στόχους. Ο πρώτος είναι να αυξηθεί η επίγνωση για το συγκεκριμένο θέμα, που έχει γίνει αντιληπτό από συγκεκριμένους υπαλλήλους, μέσα στην εταιρεία. Μέχρι πρόσφατα, η προσοχή όλης της εταιρείας ήταν στραμμένη στα προηγούμενα μοντέλα του μηχανήματος, και δεν υπήρχε η ανάγκη για καταγραφή του περιβάλλοντος των μηχανημάτων, διότι η παραγωγικότητα τους ήταν πάνω από 90%. Ωστόσο, τα μηχανήματα με τη νέα τεχνολογία είναι αρκετά πιο πολύπλοκα, το οποίο αναγκάζει τους μηχανικούς της εταιρείας να σκεφτούν λύσεις με περισσότερες αναμειγμένες παραμέτρους. Παρόλα

ταύτα, οι άνθρωποι δεν είναι θετικοί στις αλλαγές της ρουτίνας της δουλειάς τους, γι' αυτό ένας από τους στόχους της παρούσης εργασίας είναι να επιδείξει τη σημασία του προβλήματος, ώστε να ληφθεί υπόψην από όλη την εταιρείας. Το τρίτο και τέταρτο κεφάλαιο είναι αφιερωμένο στον σκοπό αυτό, αναλύοντας την κατάσταση της εταιρείας και διατυπώνοντας αναλυτικά το πρόβλημα.

Ο δεύτερος στόχος της εργασίας ήταν, η ανάλυση της κατάστασης και ο σχεδιασμός των απαιτήσεων ενός συστήματος που θα αντιμετώπιζε το προαναφερθέν πρόβλημα. Η ανάλυση πραγματοποιήθηκε με έρευνα όσο το δυνατόν περισσοτέρων ομάδων ανθρώπων και σεναρίων χρήσης μέσα στις δυνατότητες του ερευνητή, δεδομένου ότι οι περισσότερες διαδικασίες που αναφέρονται στην παρούσα εργασία λαμβάνουν χώρα σε όλο τον κόσμο και αφορούν μεγάλο αριθμό ατόμων. Το αποτέλεσμα ήταν η ανάλυση να χρειαστεί να περιοριστεί στις διεργασίες στις οποίες θα είχε το μεγαλύτερο αντίκτυπο η έλευση ενός συστήματος που θα ικανοποιούσε το προαναφερθέν πρόβλημα. Ομοίως οι απαιτήσεις που σχεδιάζονται αλλά και οι λύσεις που προτείνονται έχουν ως σημείο αναφοράς τις συγκεκριμένες διεργασίες. Καθ' όλη την έκταση του κεφαλαίου πέντε, η ανάλυση και η εξαγωγή των απαιτήσεων παρουσιάζεται.

Ο τρίτος στόχος της εργασίας ήταν η διερεύνηση ενός πληροφοριακού συστήματος, το οποίο θα είναι σε θέση να εκπληρώνει τις απαιτήσεις, αλλά την ίδια στιγμή να είναι συμβατό με την λοιπή σύνθεση της εταιρείας. Η διερεύνηση αυτή πραγματοποιείται στα κεφάλαια έξι έως οκτώ.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

CS	Customer support
CS FF	Field factory
D&E	Development and Engineering department
DFD	Data flow diagram
MACHINE X	MACHINE X machine's technology
MACHINE X	Extreme ultra violate
IRM	Installation requirements manual
FAB	Production facilities in a cleanroom
GUI	Graphic user interface
HVM	Heavy manufacturing
IC	Integrated circuit
ICT	Information & communication technology
MRM	Maintenance requirements manual
NPI	New product introduction
MACHINE X	COMPANY X's product
PLM	Product lifecycle management
PM	Preventive maintenance
SPA	Site preparation audit
USD	Unscheduled down

1. INTRODUCTION

COMPANY X is a company that produces lithography systems. These systems perform the most critical step in the production of integrated circuits, also known as chips. The latest addition to the range of systems that COMPANY X produces is the MACHINE X system. The MACHINE X system can illuminate with high accuracy, and therefore it can produce highly detailed chips, to the level of nanometers.

In order to prevent unidentified problems that will result to unscheduled downtimes of the machines and to have the tools to plan with more precision actions on the field, COMPANY X wants to implement a system to keep track of the situation in the customer facilities. The current way of acquiring and maintaining the information for the field is based on personal initiative, which is far from ideal, and thus numerous problems remain unresolved. This investigation will make a contribution towards the solution of this problem, by exploring a better fitted system that will concentrate, display and analyze the data received from the field.

The objective of this research study is to provide a proposal for a new information system to handle customer site relevant, confidential information. The goal of the proposed new information system is to promote a more efficient and cost reduced way of working throughout the company.

In the near future, COMPANY X expects the volume of MACHINE X machine sales to go through a steep increase, since the HVM (Heavy Manufacturing) phase for the machine will be introduced. By HVM, COMPANY X declares that the machines are at a performance state, to be used by customers in their production lines. Because of that increase of machines on the field, the efficiency of the processes of handling that crucial information for actions on the machines, must increase to meet the expected needs that will occur.

2. STRUCTURE OF THE REPORT

This report consists of 7 parts: An introduction to the company, the research design, the use cases analysis, the process flows and roles, the information system analysis, solution proposals and comparison of them, and the conclusion.

In chapter 3, the company at which this research has been conducted will be introduced. The business environment will be explained together with the current strategy and way of working.

In chapter 4, presents the problem definition and the scope of the research. The research tools and the methodologies are displayed, that are going to be used for each part of the research.

In chapter 5, the analysis of the use cases for the system in question will take place. The major use cases are elected and from thorough analysis the requirements for the system in question are highlighted.

Chapter 6 analyses the processes to support the system in question will be presented and the tasks that need to be performed by the suited roles will be allocated and identified.

Chapter 7 covers the theory for the information system architecture, and the current situation of the company is presented. Afterwards, using the analysis from the previous steps, the desired system design is introduced and the suitable architecture.

Chapter 8 presents the possible information system solutions for the problem in question. Analyses the solution with the key indexes that have been found in chapter 7, and compares them showing their advantages and disadvantages.

Finally in chapter 9, the solution that seems more fitted with the requirements of the project is presented. In addition the whole project experience is evaluated and the difficulties that occurred during the project are discussed.

3. RESEARCH DESIGN

This section will outline the challenges COMPANY X is dealing with, with regards to their MACHINE X systems. The research analysis will be introduced, both the techniques that are going to be used as well as the content.

3.1 PROBLEM DEFINITION

Recently, COMPANY X's strategy changed with respect to the MACHINE X light technology. Initially, it started as a test project without any reassurance that it will ever be a machine in mass production which uses this technology. However, since the first MACHINE X machine 3100 revealed to the industry that it could play a significant role, COMPANY X crafted the new strategy for the future, with MACHINE X machines as its flagship. But, as previously stated, the MACHINE X systems even after 5 years of development suffer from low availability. Unscheduled Downtime and Scheduled Downtime account for around 25 percent and 20 percent unavailability respectively. To make these systems suitable for large-scale production COMPANY X wants to steadily improve the availability over the upcoming years to 90 percent. In order to achieve this, different sets of actions are scheduled to be undertaken.

This project is focused on one of these actions, which deals with the problem of communicating the information from inside the customer's facilities to the company's headquarters. The environment that surrounds the machine is crucial for the planning of maintenance actions, upgrades to the machines, and for several other uses that will be explained in more depth in the next chapter.

The main problem COMPANY X is facing trying to collect that data, is the confidentiality policies a lot of its major customers have. One of the key characteristics of the semiconductor industry is the high technological innovation that drives the field, which makes all the companies reluctant to share their company secrets even with their partners. This policy, which for a share of customers extends to, one could say, unreasonable levels, has been an obstacle in standardizing the process for collection of this information. Nevertheless, since that information is essential for plenty of action being performed by COMPANY X to the customer's site, eventually this information lands somewhere within COMPANY X.

Having said that, no one should assume that finding this information is an easy task, and usually this situation, leads to frustration to anyone who tries to.

One way that this information is getting documented is the following. When a customer decides to purchase an COMPANY X MACHINE X lithography machine, the Factory Preparation engineers from the installation department go to the customer site in order to prepare the facility (Fab & Sub-Fab) and the staff for the imminent arrival. At that moment, among other procedures, the engineers need to fulfill several audits with requirements that the customer's facility must be in accordance with.

Currently, these surveys are the only records that COMPANY X keeps, which contain information about the customer sites. However these are not detailed or even updated. The surveys only specify whether the customer sites conform to several benchmarks for installation, without a lot of times, including actual information about the site's infrastructure. In addition, due to the surveys' format and the lack of accessibility from the rest of COMPANY X's intranet, other departments are not aware and cannot access those documents.

Another way that currently the stakeholders obtain information about the surrounding of the machine is by visiting the sites personally. Of course this means that they have to fly all over the world and most often, to Asia or USA. As anyone can imagine, these voyages costs a lot of money to the company, and a considerable loss of human resources. The worst part is that still no one from another department of the company knows who has already been to a trip to which site and knows the details that they are interested at. If they are lucky, they could find out the information holder before they travel themselves, but also this won't happen without an exhausting sequence of emails within the company.

Overall, it is obvious that there is a need for a standardized procedure, so all the stakeholders can be aligned as to how and where they can retrieve the information required.

3.2 TRIGGER OF THE PROJECT

Crucial factor of the MACHINE X machines availability for production by the customers is the minimization of the time consumed for maintenance actions on the machine. For that purpose COMPANY X wants to implement a preventive maintenance actions planner that will be able to merge actions with similar steps together, and plan as well for parallel activities, to the extent that this planning is capable by limitations. Limitations such as same crane used for multiple machines, or distance between consecutive machines are essential for the successful planning. At this point the missing link for operating this new system was clear. The need for an information system that contains that kind of information became obvious.

3.3 SCOPE

This research work will focus on identifying the desired to-be situation and make a suitable proposal. The creation of such an IT solution with the actual processes to support it falls beyond the scope of this project.

The research study will be divided into five parts. The first part will be about the possible way of use for a system like this. The "WHO" will define the exact requirements as well as the needs in terms of information that the system must contain. In this part the study will extend to uses further than the preventive maintenance planner, since more stakeholders within COMPANY X can be identified, and be benefited.

The second part will be focused on the processes and the tasks to be performed for the system to operate in an optimized way throughout the actual structure of the company. There will be an analysis of the current standardized roles and their tasks in order to identify where the management of the system should land. If no suitable role is identified, then a proposal for creating a role to perform the needed tasks will take place, and also the characteristics of this role.

The third part will be dedicated to the conversion of the previous analysis steps into IT requirements. The goal will be to design the ideal structure of the information system. Also, the architecture of the system will be established. Next, an analysis will be performed to identify the indexes that are important for the needs of the identified information system, and on these indexes the solutions will be evaluated in a later stage of this research.

In the fourth part possible solutions are going to be discussed. Initially, the solutions that will be identified will come from within the company as less expensive. Afterwards, and only if the internal solutions are not adequate enough, the research for solutions will be broaden outside of the company. Due to lack of time this part will not be executed with actual offers from third-party companies, but with a comparison of their aspects with the needs for the system.

In the last part of the research a comparison will be made throughout the solutions identified to propose the one that by the researcher and his advisors perspective will be the most suited for the company.

3.4 RESEARCH TOOLS

The main research tools that are going to get used for this project are:

- Interviews
- Workplace
- Library research

Interviews are all about identifying, from experienced people within the company, the current situation and how they imagine the future one. By this, valuable information is being extracted considering which problems seems to be more important in the as is situation. In addition, information could be extracted regarding the processes of the company and the way that this organization confronts and solves the challenges it encounters.

By workplace this project identifies the research that happens inside the company. This means for the researcher that he tries to identify the situation by exploring and engaging himself to the company's everyday operation. This way the investigator can familiarize and understand in a deeper level the company's processes and targets.

The last tool is the library research. The library research is not anymore confined in libraries, but extends to all the scientific documents someone can find in the internet. For this research articles where searched in google scholar and to IEEE Xplore digital library, because of COMPANY X's collaboration with this digital library.

3.5 INFORMATION SYSTEM DEVELOPMENT METHODS

System development methodology refers to the outline that is used to structure, plan and control the development process of an information system. Many different methods have been evolved over the years, each with its own major advantages and disadvantages. Not every available methodology is appropriate for every project. Each of the existing methodologies is a better match to specific type of projects, based on various technical, organizational, project and team composition considerations.

In this chapter the different type of the most well-known development methodologies are going to be presented, along with their strengths and weaknesses. This analysis was necessary for this project in order to determine which methodology best suits the course of this assignment.

3.5.1 Waterfall

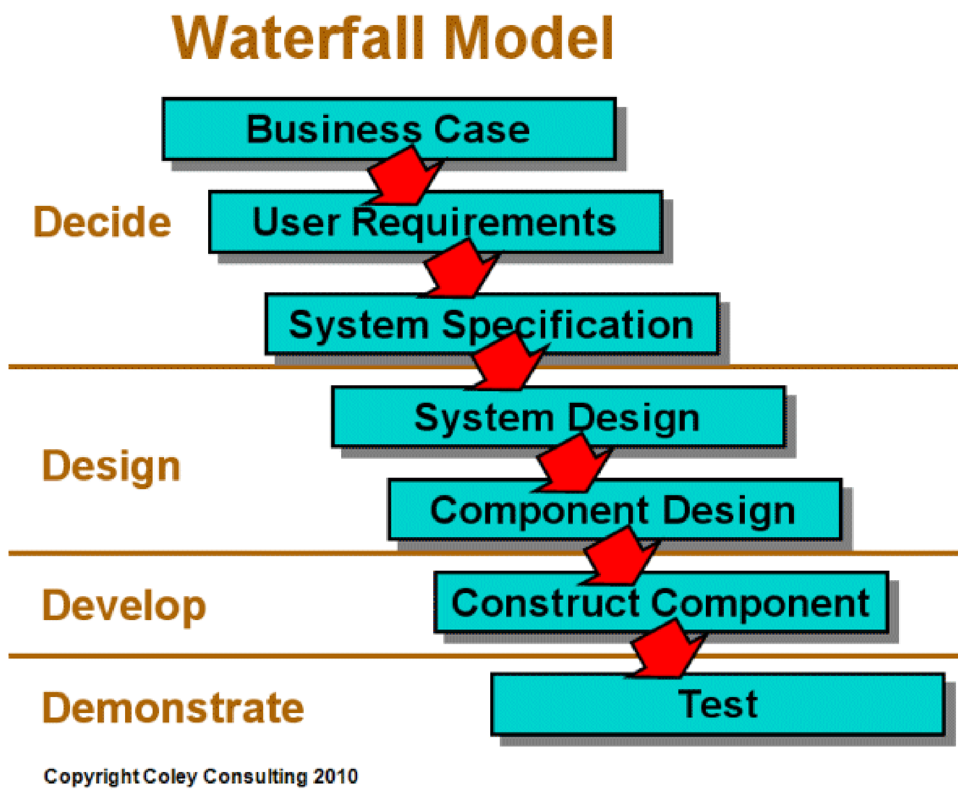


Figure 1 - Waterfall development method (Coley consulting 2010)

Type of framework of this method: Linear

Main Principles:

1. Project is divided into consecutive phases, with some overlay and the possibility of going back acceptable between phases.
2. The emphasis is given on planning, time schedules, target dates, costs and implementation of the complete system at one shot.
3. Tight control is maintained over the lifecycle of the development through the use of broad written documentation, as well as through formal assessments and approval/signoff by the users and information technology management, taking place at the end of most phases.

Strengths:

1. Ideal for supporting less proficient project teams and project managers, or project teams whose composition varies.
2. The organized sequence of progression steps and strict controls for ensuring the competency of documentation and design reviews helps maintain high quality, reliability, and maintainability of the developed software.
3. Progress of system development is quantifiable.
4. Preserves resources.

Weaknesses:

1. Unbending, slow, costly and bulky due to substantial structure and close-fitting controls.
2. Project advances forward, with only minor movement backward.
3. Little possibility for use of iteration, which can have an impact on manageability if used.
4. Relies upon prompt identification and specification of requirements; however users may not be able to clearly outline what they need in early stages of the project.
5. Discrepancies on requirements, missing system components, and unexpected development requirements are often exposed during design and coding.
6. Complications are often not exposed until system testing.
7. System efficiency cannot be tested until the code is almost fully completed, and capacity issues may be challenging to correct.
8. Hard responses to changes. Changes that occur late in the development lifecycle are more costly and are thus avoided.
9. Produces too much documentation and keeping it up to date as the project evolves is time-consuming.
10. Written specifications are often difficult for users to read and completely appreciate.
11. Increases the gap between users and developers with clear separation of responsibility.

Situations where most suited:

1. The project is for development of a batch system mainframe-based or transaction-oriented.
2. The project is large, costly, and complex.
3. The project has clear objectives and solution.
4. No pressure exists for immediate implementation.
5. The project requirements can be stated clearly and understandably.
6. The requirements of the project are rigid or unchanging during the system development life cycle.
7. User community is experienced in the business and application.
8. The team members may be unexperienced.
9. Team composition is unstable and expected to alter.
10. Project manager may not be fully experienced.
11. Resources need to be preserved.
12. Strict requirement may exist for formal approvals at milestones.

Situations where least suited:

1. Large projects where the requirements are not well agreed or are changing for any reasons such as external changes, budget changes, rapidly changing technology or changing expectations.
2. In a situation of a Web Information Systems (WIS). Primarily due to the pressure of implementing a WIS project quickly; the need for experienced, flexible team members drawn from multiple disciplines; the continual evolution of the project requirements; and the inability to make assumptions regarding the users' knowledge level.
3. Real-time systems.
4. Event-driven systems.
5. Leading-edge applications. (Khalifa & Verner 2000)

3.5.2 Prototyping

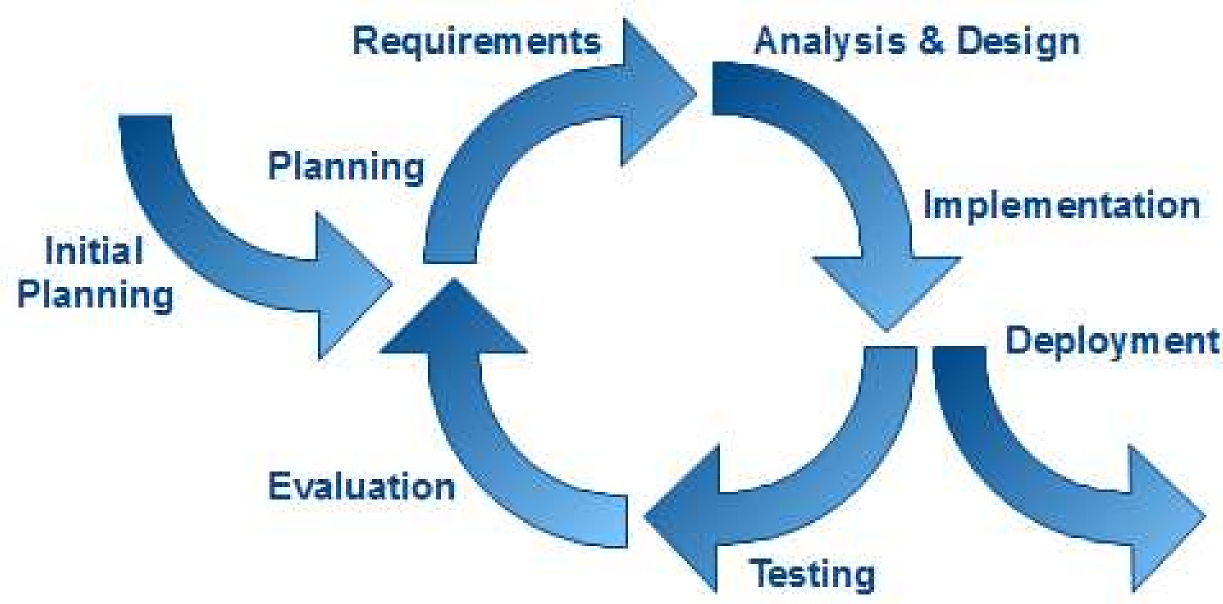


Figure 2 - Prototyping development method (Agilerules.blogspot.com, 2014)

Type of framework of this method: Iterative

Main principles:

1. Is not referred to an independent, complete development methodology, but more likely a tactic to handling selected percentages of a larger, more conventional development methodology (e.g. Incremental, Spiral, or Rapid Application Development.
2. There are attempts to reduce in-built project risk by breaking a project into smaller segments and providing more ease-of-change during the development process.
3. A major understanding of the core business problem is essential to avoid solving the wrong problem.
4. The user is involved all over the process, which increases the prospect of user acceptance of the final implementation.

5. Minor prototypes of the system are processed until the whole prototype develops to meet the users' requirements.
6. Though most prototypes are developed with the anticipation that they will be discarded, it is possible in some cases to develop from prototype to working system.

Strengths:

1. "Addresses the inability of many users to specify their information needs, and the difficulty of systems analysts to understand the user's environment, by providing the user with a tentative system for experimental purposes at the earliest possible time." (Janson and Smith, 1985)
2. "Can be used to realistically model important aspects of a system during each phase of the traditional life cycle." (Huffaker, 1986)
3. Particularly useful for solving vague objectives; developing and authenticating user requirements; testing with or comparing various design solutions; or investigating both performance and the human interface.
4. Affects positively both the user participation in system development and communication amongst project stakeholders.
5. Could generate specifications for a production application.
6. The possibility exists for exploiting knowledge gained in an early iteration as later iterations are developed.
7. Provides rapid implementation of a partial, but functional application.
8. Advantages on easily identifying confusing or difficult functions and missing functionalities.
9. Supports innovation and flexible designs.

Weaknesses:

1. The approval process is not strict and the same holds for the control.
2. Requirements can significantly vary.
3. The system often appears complete when in fact it is not yet functional. This can lead to false expectations from the customer's side.
4. The focus may fall on the most remarkable and obvious needs, making an inadequate problem analysis very probable. This can possibly result in implementing unproductive methods into the new system.

5. Prototyping is often insufficiently controlled and due to the designers' rush and inadequate customer analysis the produced design may not meet the actual requirements.
6. Documentation may be neglected, causing unsatisfactory justification for the final product and poor records for the future.
7. Non-functional requirements are difficult to be explained in a document.
8. System can be poorly designed. Designers that have small or no experience may confuse prototyping for rigorous design, which can cause to "messy" solutions without thorough consideration of the integration of all the components.
9. Iterations can cause extra costs and delays to the project. Consequently, very small projects might not be able to justify the added time and money.

Situation where most suited:

1. For development of an online system that requires extensive user dialog, or of a low level expertise and decision support system.
2. No requirements for completely minimizing resource consumption.
3. Project that includes many users, interrelationships, and functions, where project risks related to requirements definition needs to be reduced.
4. Project objectives are not clearly defined.
5. Analysts/users, are aware of the impact of the business problems considered, before they begin the project.
6. Project with high priority that requires direct implementation..
7. Functional requirements may often vary considerably.
8. Low experience and expertise on the user's side.
9. Team members are experienced (particularly if the prototype is not for one-time use).
10. Team composition is stable.
11. Project manager is experienced.
12. No approval necessarily required at designated milestones.
13. Innovative, flexible and extendable designs are not essential.

Situation where least suited:

1. Mainframe-based or transaction-oriented batch systems.
2. Web-enabled e-business systems.
3. Team composition is not stable.

4. Scalability and modularity of the design is critical.
5. Project objectives are very clear; low risk considering the requirements definition. (Khalifa & Verner 2000)

3.5.3 Incremental

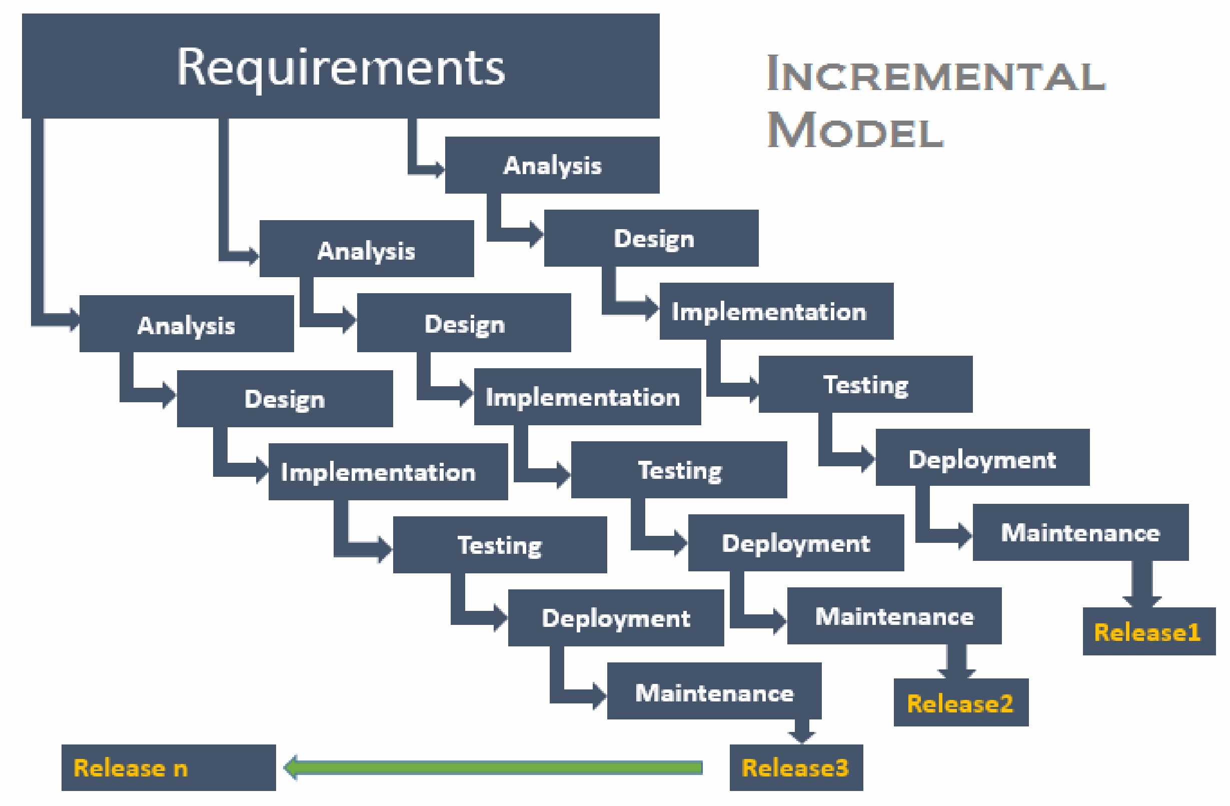


Figure 3 - Incremental development method (Testingfreak.com)

Type of framework of this method: Combination of Linear and Iterative

Main principles:

Many methodologies combine linear and iterative system development methods. The main objective of each is to reduce inherent project risk by breaking the project into smaller parts and providing more flexibility during the development phase:

1. A series of mini-Waterfalls are performed, where all phases of the Waterfall development model are completed for one part of the system, before going on to the next increment.

2. Overall requirements are defined from the beginning.
3. Waterfall approach is used for the initial software concept, requirements analysis, and design of architecture and system core, followed by iterative Prototyping, which concludes the installation of the final.

Strengths:

1. Important knowledge gained in an early increment can be used later on the following increments.
2. Documentation, formal review and signoff by the user on important predefined milestones are used to control the project throughout its life cycle.
3. Stakeholders have the possibility to monitor the project's status.
4. Facilitates the mitigation of integration and architectural risks earlier in the project.
5. At every increment the implementations are gradually more complete and thus production comes more quickly.
6. Gradual implementation allows more detailed monitoring of the changes, isolation of issues and so the organization can easily adjust to avoid severe negative impact.

Weaknesses:

1. To demonstrate early success to management difficult problems tend to be pushed to the future.
2. Since there is a high focus on every small part of the system the overall picture more easily may be forgotten.
3. Well-defined interfaces are required, because some modules will be completed much earlier than others.

Situations where most suited:

1. Leading-edge applications.
2. Large projects with not very clear or constantly changing due to external disturbances requirements, budget changes, changing expectations or rapidly changing technology.
3. Web Information Systems (WIS) and event-driven systems.

Situations where least suited:

1. Very small projects of very short duration.
2. Very low integration and architectural risks.
3. Highly interactive applications with pre-existing data.
4. When the project significantly involves analysis or reporting of data. (Victor 2003)

3.5.4 Spiral

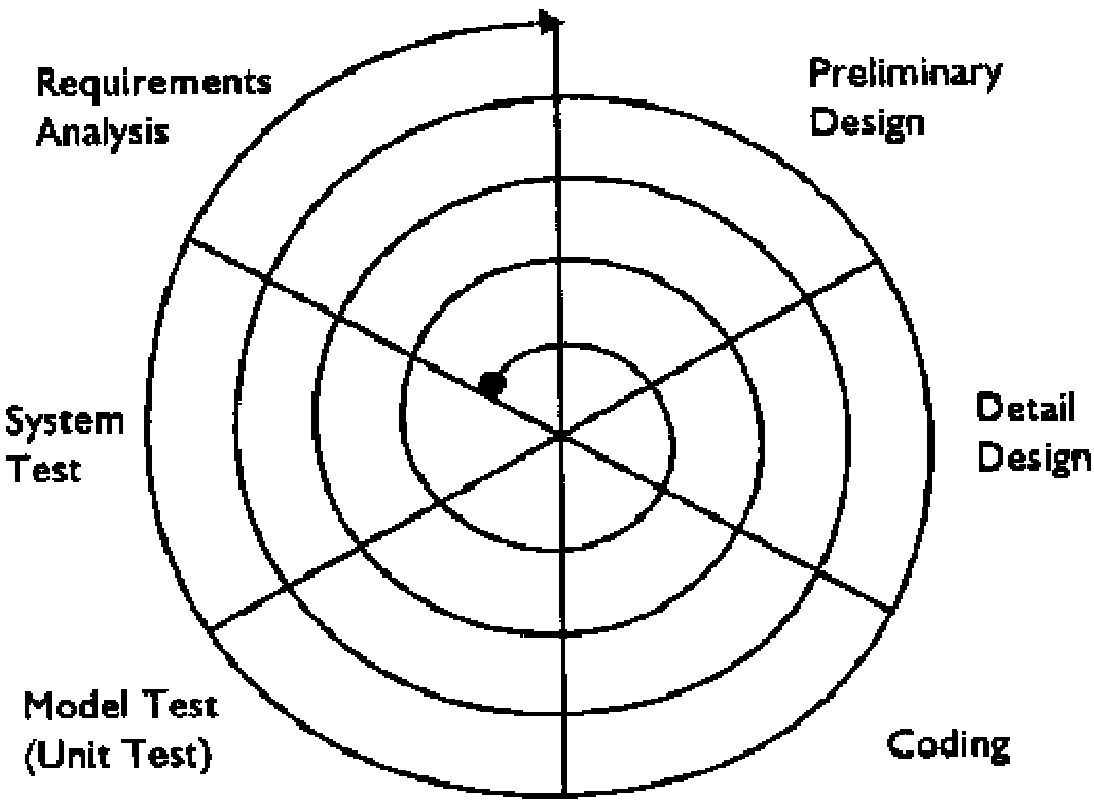


Figure 4 - Spiral development method (acqnotes.com)

Type of framework of this method: Combination of Linear and Iterative

Main principles:

1. Risk assessment is the goal and particularly minimizing the projects potential risks by splitting the project into smaller parts that can be easily addressed and adjusted.
2. Start every cycle with a stakeholder analysis that includes the identification of the stakeholders and their objectives.
3. Each cycle involves the same amount of progress, the same methodology and the same depth.
4. There are four basic quadrants to pass in each cycle around the spiral: (1) definition of the objectives, alternatives and limitations of the iteration; (2) evaluation of the alternatives; identification and mitigation of the risks; (3) development, validation and verification of the deliverables; and (4) planning of the following iteration.

Strengths:

1. Risks are identified at an early stage and therefore are easily avoided.
2. This method can incorporate Waterfall, Prototyping, and Incremental methodologies or even a combination of them taking into account the highest priority risks.

Weaknesses:

1. The selection of the composition of the aforementioned methodologies which can be incorporated is challenging.
2. Since it is customized to each project, the complexity increases and the reusability is minimized.
3. No hard deadlines are set and so being on schedule becomes difficult. There might even occur that the budget is exceed because of the same reason.
4. High expertise in terms of project management is required to ensure successful use of the method.
5. There is no specific control strategy between cycles and that can cause extra work when things are omitted or neglected.

Situations where most suited:

1. Safety-critical and real time systems.
2. There is great expertise in terms of project management.
3. A high priority has been given to ensure no risk.

4. There is flexibility on the use of resources.
5. Implementation is more important than functionality, while the latter can be added at a later stage.
6. Strong approval and documentation control is a top priority requirement.
7. High level of accuracy is required.

Situations where least suited:

1. Avoiding risks is not so important.
2. The use of resources is limited.
3. Functionality is more important than implementation.
4. High level of accuracy is not required. (Boehm 1988)

3.5.5 Rapid Application Development (RAD)

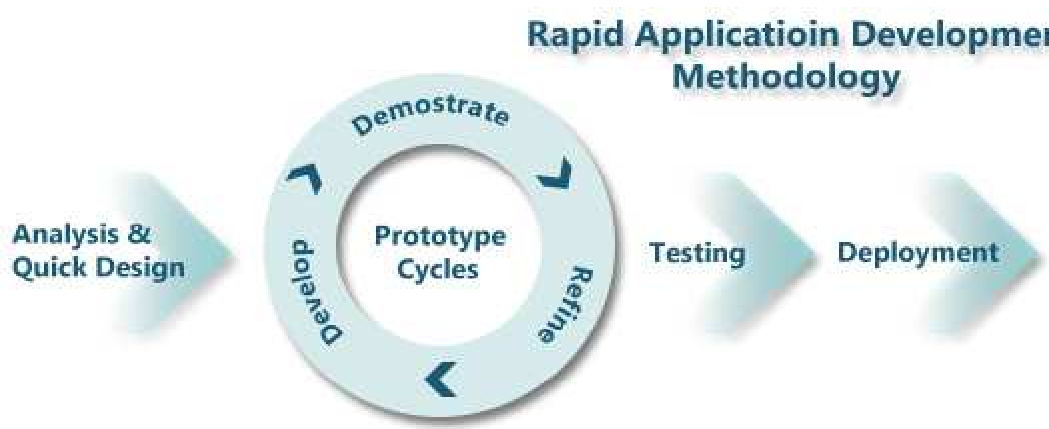


Figure 5 - RAD method (Agilerules.blogspot.com, 2014)

Type of framework of this method: Iterative

Main principles:

1. For fast development and delivery of a high quality system that comes with a relatively low investment cost.

2. Reducing the project risks by splitting the project into smaller parts and addressing every part as a separate project during the development process.
3. It includes Joint Application Development, where the users significantly contribute in system design.
4. The goal is to generate high quality systems fast, using iterative Prototyping, active user involvement, and computerized development tools such as Graphical User Interface builders, Database Management Systems , Computer Aided Software Engineering tools, code generators, and object oriented languages.
5. Active user involvement is crucial.
6. Focus primarily on the business aspect, while technological or engineering parts are less important.
7. Control strategy includes prioritizing development and setting deadlines. If delays occur then the requirements are reduced and the deadline does not change.
8. Compatible with standard systems analysis and design techniques.

Strengths:

1. The product is functional much earlier than with Waterfall or Spiral framework.
2. Engages the stakeholders at a high level of commitment, both business and technical. Users have a greater sense of ownership of a system, while developers are more satisfied by producing successful systems fast.
3. Since RAD produces systems more quickly and has a focus on the business aspect, these systems usually come at a lower cost.
4. The important system characteristics are assessed from the user's point of view.
5. Allows for direct adjustments based on the users' demands.
6. System specifications are directly related to the user objectives and requirements.
7. Time consumption, human effort and money are reduced rapidly.

Weaknesses:

1. System quality may decrease due to the high speed and low cost of development.

2. High speed can lead to omissions that subsequently could result in misalignment between the developed systems with the original customer's vision.
3. Reusability and scalability of the module on future systems is difficult.
4. More requirement than required might arise (gold-plating). Thus more and more features can be added and make the system more complex.
5. The design may contain inconsistencies regarding programming standards and related documentation.
6. High risk of overlooking the administration needs built into system.
7. High commitment on the side of the user personnel is required.
8. Implementing formal reviews and audits needs more effort than for a complete system.
9. High risk of pushing important issues towards the latest stages of the project in order to show early success to management.
10. Well-defined interfaces must be set, since the structure is modular and some modules are completed much earlier than others.

Situation where most suited:

1. For small-medium projects of short duration.
2. Developers are familiar with advanced tools
3. Business objectives are of high priority.
4. Users have a certain level of knowledge on the application field.
5. Highly interactive application, with a specific user group.
6. Team composition is ensured; no significant changes within the life cycle of the project.
7. Functionality of the system is obvious through the user interface.
8. System requirements are not clearly defined on time.
9. Team members have very good social and business skills.
10. Efficient control strategy is available..
11. There is available data, while the project mostly consists of data analysis.
12. The architecture of the system is well defined.
13. Basic components are tested and in position.
14. Technical requirements like the response times, database sizes, etc. are reasonable in terms of technology.
15. The development team is fully authorized to make decisions, without an approval from their supervisors. So the process is fast.

Situation where least suited:

1. The business objectives are not clear and the overall project scope is vague.
2. Very large projects that consider distributed information systems.
3. Safety-critical and real time systems.
4. System that involve the analysis of complex, high volume data.
5. Decisions are taken by a large group of people that usually are not available much and do not necessarily work from the same location. High focus must be given to coordination of this type of team.
6. When the functional requirements have to be fully defined before the start of development.
7. Technical requirements such as the response times and database sizes are limited by the used equipment.
8. User resources are not fully committed to the project.
9. High level of innovation to be introduced within the scope of the project, or the technical architecture is not clear enough. { Beynon-Davies, 1998}

3.6 METHODOLOGICAL PROJECT APPROACH

This chapter presents the research methodology. It provides an overview of the actions that will be taken and the tools which are going to be used for coping with each part's tasks.

After careful consideration of the positive and negative attributes each method has to offer, the selected one is the waterfall method. The main reasons are the limited resources (one man team) and the stability it provides throughout the research, which is important for the final outcome of this project, since it is also a master thesis. The steps of the waterfall method that will be implemented are the following:

- Initial phase or requirements phase
- Design phase

The first step is to identify the use cases, and that process will be described in more detail in the next chapter. In order to accomplish this, two kinds of tools are going to be used. The first one is the interviews. By interviewing experts for each field, we can identify their needs on information from the field and where exactly their operational authority lies on. The second one is the workplace strategy by which we are going to find possible use cases through the company's logged processes. Afterwards, interviews must be done in order to verify whether these use cases are realistic. Since COMPANY X is a huge company, identifying all the departments that are possibly involved and use this kind of system is almost impossible by an intern. Therefore, finally, the focus will be on the four to five major use cases and their analysis in order to take the research to the next level.

For the processes and the tasks that need to be appointed to roles, the same two methodologies will be implemented. Interviews will be taken, to map the current situation and realize the way of working, and research through the company's network will be performed to deepen my knowledge on these tasks and identify successfully the correct persons to interview. The goal is to have a description of how the system can be functional within the current infrastructure.

The third step is where the design will initiate and the following strategy will be put to work. Initially this part will begin with some literature study, to understand how to transform the previous steps into design material. Scientific documents will help to understand how the system architecture works and to identify the software key attributes which are significant to rate our system with. In the process it will be necessary to understand and map the companies' information systems and to examine whether they should be integrated with the system that is being investigated.

The identification of possible solutions will occur in two parts. The first part will be focused to the existing company infrastructure, and the goal will be to extend it in order to be able to complete the desired extra functions. For this part, interviews and workplace research will be very crucial. The second part will include research for a solution outside COMPANY X's network capabilities, and mainly the research on the web strategy will be of use. Also interviews of IT personnel will be needed to acquire the knowledge of the processes for obtaining and implementing new systems within the organization. This part is very hard to complete and only if the time constraints are favorable it will occur.

Finally, the solutions of the previous steps will be subjected into an evaluation with the indexes identified in previous chapter. This comparison will show which solution is more suitable for solving COMPANY X's current problems.

Below a diagrammatical representation of the methodological approach is being presented.

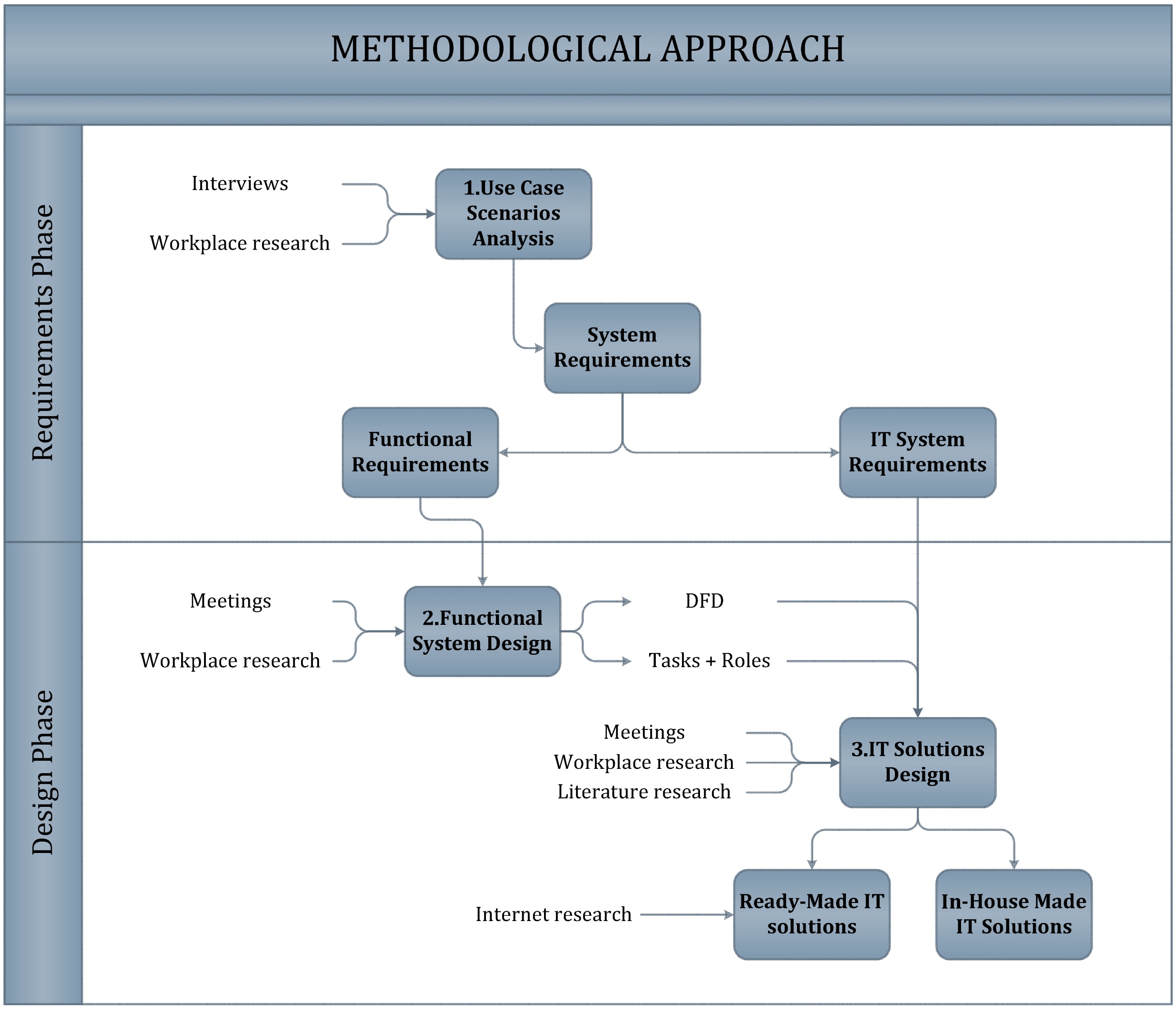


Figure 6 Project's methodology approach

4. USE CASES SENARIOS

This section is about the use cases analysis which is the first step of the project's methodology which is presented in the sub-chapter 4.6. The process of the discovery will take place and an analysis for each one of them. Afterwards an even more thorough analysis will occur for the chosen major use cases, and based on them the rest of the research, will be conducted at the next steps.

During this research, use cases will refer to high level uses of the system under investigation considering also the department that will be using it. There should be no confusion with the low level, high detail use-cases of the software creation process.

4.1 ALL POSSIBLE RECOGNIZED USE-CASES

After several meetings with my mentor, and interviews with a broader group of people with extensive knowledge on the company's processes, the possible uses of the system come down to the following actions and departments responsible for them. The cases presented are divided in two sections. The first section contains actions designated for operational use. This refers to either everyday actions on the machine or future planned actions and the preparation needed. The second section is considers business strategies and research-development purposes.

Some use cases may seem to be identical but the departments that are responsible for planning those actions are different. Since the purpose of the information system is to overcome the communication barriers between departments, these use cases will be investigated separately.

It is important to emphasize that COMPANY X engineers are not located inside the customers' sites and Fabs, unless there is an action to be performed. This situation makes the collection of information even harder, and creates the need for preventive gathering of the valuable data.

4.1.1 Execution use cases

The table below shows all the execution use cases that have been identified for the system.

Use case	Responsible department
Pre-install	MACHINE X Factory-Factory preparation
Install	MACHINE X Factory-System install output
De-Install	MACHINE X Factory-Customer Support
Preventive maintenance Planner	Customer Support NPI
Unscheduled Downs	Customer Support FF
Hardware FCOs	Customer Support FF
Software FCOs	Customer Support FF
Complex Upgrades	Development & Engineering / CSU
Customer changes on the field	Customer Support FF

Table 1 Execution use cases

In order to decide with one of them will have the biggest impact and influence on the system's development proposal, an analysis needed to take place. For each use case I scheduled a meeting with the corresponding department and I tried to understand their respective contribution to the operational chain of processes and procedures. How did every one affect the final product?

- Pre-Install

  As already described, the MACHINE X machines have a lot of requirements in order to operate. Some of them are the cleanliness of the environment, the high usage of electricity, and the isolation from the environment. In order to achieve these requirements, before the installation of the machine at the customer's site, a lot of preparations need to take place. All these preparations and requirements are documented in a manuscript called IRM (Installation requirements manual). Several months before the machine installation, COMPANY X engineers are sent to the customer, with the purpose to assist and educate the local customer's team on how they should build the facilities, in order to be according to specifications for the imminent machine arrival. The customer is responsible for preparing the facilities according to specifications, and the engineers from COMPANY X are responsible to guide and assist the customer, and at the end of the phase to validate that the situation is indeed suitable for the next step, which is the machine mechanical installation. During the validation, the engineers acquire lots of information from the environment of the machine, in order to find any deviations from the predefined parameters. This information could be a valuable input for the system under investigation.

- Install

  After the preparation of the facilities, the machine comes in pieces. The installation phase has two parts. The first one is the mechanical installation, where all the parts are assembled together and the functionality of every one of them is checked. The second one includes the calibration of the whole system. This second phase could last even longer than the first one because of the complexity of the machine. During the installation process, many documents with regards the machine functionality, which are important for future diagnostics of problems that occur in the machine, are gathered. These documents currently are passing to the CS department after the successful installation and the SAT (site acceptance test). However, no other departments have access to the information on these documents.

- De-Install

The De-Install action occurs when a customer sells a used machine back to COMPANY X. Then COMPANY X refurbishes the machine and sells it as a used system to another customer who wants to create IC's, but doesn't have too high tech needs of the chips. Regarding the MACHINE X system, though, no used machines have been sold yet, and the De-Install occurs because the first version of the machine was installed only for research and will never be used for production. Nevertheless, in the future the same pattern will be followed with the MACHINE X machines, as with all the other machines,. For De-Install information from the field will be valuable for planning accurately and efficiently the course of action.

- Preventive maintenance Planner (PM Planner)

Until recently, the maintenance strategy of COMPANY X for the MACHINE X machines was corrective maintenance, because the parts are relatively expensive and the reliability of the whole system was low. However, since the machine has evolved and the parts' quality has improved, as well as the machines' overall functionality, a more efficient method of maintenance should be introduced. The method chosen is preventive maintenance with scheduled downs of the machine.

The maintenance actions are separated in three stages. The first one and the third one are access and recovery of the machine respectively, which are the same for the majority of the actions. Since the machine is working within a vacuum environment with dangerous chemical substances, the access of the machine and the recovery are two very time consuming activities. Therefore, parallel repairs on the machine could be very efficient in terms of time, but the complexity of those actions makes it hard for the engineers to identify possible actions that can be performed in parallel. Currently NPI division is working on a project trying to implement a generic way of creating the planning for all the machines, with the functionality to propose to the engineers at task, actions that could be performed at the same time with the one that they have already planned to do. Of course, other parameters will also be taken into account, such as the remaining time of the component that will be changed etc.. In order to create the sequence action planning, information from the environment of the machines will be needed, such as the number of cranes available, or the space between consecutive machines, also known as service area. The information system under investigation could provide this information.

Below the roadmap of the optimized PM planning automated systems is presented, and how it is connected with this project. All the green components are going to be explained in a later chapter, where the current status of the company is going to be analyzed, whilst the Operations Manager box indicates the components of the PM Planner, which are under investigation and development as well.

- Unscheduled Downs

The unscheduled downs occur when the machine stops the manufacturing process or the engineers need to stop it, due to underperformance of the machine. The procedure is almost the same as scheduled downs with the important addition that first the problem should be identified, and then the tools and parts must be transferred to the location for the repair. The problem identification is called diagnostics, and due to the complexity of the machine, this could be one of the toughest tasks for engineers within COMPANY X. To execute diagnostics, access with a computer on the machine is needed, to extract data that receiver instruments on the machine have collected. The connectivity situation for each Fab is completely different and depends on the customer, even though the ideal situation from COMPANY X's perspective has been issued and handed over to the customer. For that reason, it would be very useful for the planning of the diagnostics procedure to have the connectivity map for each location filled and easily reached. The transfer of the tools and parts is handled by the logistics department, until they are transferred to the customer. However, the customers have specific days that allow those imports to the Fab, for prevention of contaminating the machines. Also, the storage space inside the Fab is not usually standardized by the customer, so there is no standardized way of controlling the available space given to the company. This kind of information would be valuable for the respective engineers.

- Hardware/Software FCOs

FCO stands for Field Change Order. These actions are improvements, that have been found after the machine is already installed in the costumer. They are usually improvement modifications and the expertise needed to perform them is among the local engineers. No further assistance is needed from D&E and usually there is no need to extract one of the main modules of the machine in order to access the part that will be modified. FCOs are usually generated in the field and not in the lab, since they are solution for problems discovered to one or more of the machine in the working environment.

FCO are divided in four categories. The most important is the security FCO, which must be implemented immediately. The other categories with respect to the priority of the action and with concern to the performance of the machine are the operational functionality and damage prevention FCO, and lastly the kit modification FCOs. The trend lately is to implement the FCOs in parallel with the maintenance actions, which will result to decrease the machine's downtime. For FCOs actions the engineers need information from the environment of the machine to plan their actions.

- Complex Upgrades

An improvement on the machine that is very complicated to perform by the local crew is called complex upgrade. In the complex upgrades, usually, large parts of the machine need to disassemble from the main frame in order to reach more centralized parts or to be swapped. These actions are very hard to perform on the customer site, due to the limited space around the machine. The case, most of the time, is that the customer provides less space around the machines than what COMPANY X has asked for, and for that reason COMPANY X has implemented a minimum empty space around the machine in the IRM (Installation requirements manual), in order to be able to take apart some of the basic components. Still it is not possible for all the components to be removed in case it's needed. Although this empty space is a continuous bargain between the company and the costumers, since they don't want to have areas inside the Fabs, meaning expensive areas, it is left unoccupied. However, gradually the customers realize that the machine's availability can be greatly raised if the proper infrastructure is in place, so in some cases the margins are bigger than what the IRM specifies. Engineers from D&E department have realized that even small updates in the infrastructure provided for the action, could improve the overall time needed by changing the sequence of the actions, perform some of them differently or in parallel. Currently, before every complex upgrade they have to fly over to measure all the needed dimensions, but with the information system under investigation they could save a lot of money and obtain the information quicker.

- Customer changes on the field

  In order for the system to have updated data, even after the engineers have left the customer's site, it is important that the engineers get informed about every change that happens. Therefore, another use case to be considered is the communication between the company and the customer, in order to receive notification for every change that might occur in the Fab or another area that will have an impact on COMPANY X's processes.

4.1.2 Business use cases

The table below shows all the business use cases identified. In contrast with the execution use cases, business use cases are not for the everyday operations of the company. Their purpose is the improvement of the product and the services in the long run.

Use case	Responsible department
Future machine or tool redesign	Development & Engineering
Future process optimization / redesign	Customer support – Global Logistics support

Table 2 Business use cases

- Future machine or tool redesign

  Inside R&D department, engineers are continuously searching for improvements to the machines currently used on the field, as well as for better solutions for almost every aspect of the illumination process. At the same time, the tools being used on the machines (which are in majority homemade, due to the complexity of the actions that need to be performed with them) are being as well investigated for possible improvements. For example, the latest tool that is investigated in the company's labs is a fully automatic robot that accomplices most of the actions without human intervention. Such a tool will increase the speed and reduce the human errors of the procedures. For this investigation to lie on sound ground, it is essential that feedback from the environment of the machines is communicated back to the researchers, to ensure that the requirements are elected based on the correct criteria.

- Future process optimization / redesign

  One of the most vital tasks for improving the processes of a company is to identify what are the bottlenecks within the current ones. The information system which is investigated, will maintain the current situation of the customer's site, which will facilitate the identification of the improvements that could be made in processes that involve the customers' Fab. For example, some customers have specific days that are allowing tools and parts to enter their Fab. This kind of information could lead to standardization of more efficient processes on the logistics path, and also to the planning of the actions by Customer support. By the short investigation conducted at this stage, for those two departments more benefits could accrue.

4.2 MAIN USE-CASES ANALYSIS

Due to limited time for conducting the research and the complexity of the company's different departments' way of working, we have chosen for this project some of the aforementioned use cases, to analyze in depth. The basic criterion of the selection was the degree of influence the information system might inflict on the cases.

For this analysis, four questions are going to be answered for each case. **Who** is performing the action, **why** is this action being performed, **what** type of information and data are being stored-used for this action case, and finally **how** that information is and how we would like to obtain, handle, store and maintain it. After the initial analysis, an overview of the requirements of each use case is being presented.

The results of this analysis are going to be analyzed and used for generating the key attributes of the system under investigation.

4.2.1 Pre-Install

Who: MACHINE X Factory Preparation engineers (EF) → CS FF (after second system install)

Why: To ensure the customer facilities have the proper infrastructure for the correct installation and operation of the machine.

What: Critical parameters in response to IRM

- Layout specifications
- Drawings
- Pictures
- Raw data files
- Word documents

How:

AS-IS SITUATION

The description below refers to the way the situation is currently being handled inside the COMPANY X organization.

1. SPA (Site Preparation Audit)

   Through the SPA, the majority of the critical information with respect to the customer site layout is obtained in the pre-install phase. In this audit, the engineer collects data and compares them to the IRM minimum required specifications.

   1.1. Excel files
   1.2. Stored in the department's SharePoint collaboration site

   - No maintenance actions for those data currently exist, as they are only used for the pre-install phase.
   - Several cases that only the comparison information stored (in yes or no form) instead of the exact data of the parameter.

2. CCA (Crane Completion Audit)

   Through the CCA useful information, concerning to the crane, are extracted. Orientation, hoisting area and limitation are presented and compared to the minimum requirements.

   2.1. Word file
   2.2. Stored in the department's SharePoint collaboration site

   - NO maintenance actions for those data currently exist, as they are used only for the pre-install phase.

3. CSR (customer special request)

   CSR are deviations from the IRM that the customer asks for. They are being reviewed from D&E system engineers, who either approve the change pointing out the after-effects or they decline the change as the problems created by this change are not manageable.

   3.1. Word document
   3.2. Through the CSR process

- ❖ The change is either accepted or rejected, but in both cases no central storage of all the deviations can be found.

4. ICM (Installation Condition Monitor) Tool test

   To test the stiffness and the vibration of the pedestal where the machine will be installed on, the engineers perform a test with the ICM Tool. This test produces an amount of raw data (several MB of space).

   4.1. Raw data in zip files
   4.2. Stored locally in USB flash drives
   4.3. Handed to D&E department for analysis of the raw data and compare the results for being within the specification margins.
   - ❖ The raw data are being erased after the result of the test is produced.

<u>TO-BE SITUATION</u>

The to-be situation is how we would like to transform the current situation to minimize the waste in the processes and thus improve the efficiency of the processes.

1. SPA (Site Preparation Audit)

   - ✓ Obtain and log the exact data for each crucial parameter that the engineers have already examined.
   - ✓ The information should be stored in a file or a system that is integrated with the rest of the company.
   - ✓ Is well known that the information exists.
   - ✓ The information should be maintained by the local department (CS FF) that is responsible.
   - ✓ Or inform the interested party that the information is out of date and he needs to research for it locally, pointing out where he should extend his action.

2. CCA (Crane Completion Audit)

   - ✓ The information should be stored in a file or system that is integrated with the rest of the company.

- ✓ Is well known that the information exists
- ✓ The information should be maintained by the local department (CS FF) who is responsible.
- ✓ Or inform the interested party that the information is out of date and he needs to research for it locally, pointing out where he should extend his action.

3. CSR (customer special request)

    - ✓ The existence of a central file or system where all the deviations for each machine can be accessible and extractable.

4. ICM (Installation Condition Monitor) Tool test

    - ✓ The raw data should be maintained for future analysis in case of a diagnostics issue.

OVERVIEW

The main reason for using the information system is to store the information COMPANY X acquires at the pre-install actions, because they receive a lot of different requests for providing that information, and that is disrupting their daily routine.

Information system storage capacity requirements:

-Around 70 parameters (SPA &CCA) with respect to:

- ✓ Fab Structure: room heights, floor thickness, feed-through hole dimensions, floor stiffness and vibration, pillar size/grid, BTS path
- ✓ Fab Crane: crane orientation, crane height, hoist area per machine
- ✓ Move-in: air-cushion supply, move-in path dimensions, storage area

-Different format files such as .doc and .cad.

-Frequency of data generation:

- ✓ One time per machine life
- ✓ Frequency per year depends on the volume of machines purchased by costumers. Currently, this volume is low and since the duration of installation of the machine is high, a steep increase in the information provided is not expected.

4.2.2 Install

Who: CS FF Installation & Relocation

Why: The goal of this action is to mechanically install the machine in the customer's site and calibrate all the components.

What: Word documents like:

- Mechanical installation documents from source and scanner
- Drive laser tests documents
- CO_2 tests documents
- H_2 tests documents
- Site Acceptance Test (SAT – being filled by the customer)

How:

AS-IS SITUATION

All the documents are being saved in a shared drive by the Install department, for emergency cases purposes during the installation phase. After the installation is completed and the customer has accepted the machine as completely installed, all the documents are handed over to the CS department. Within the CS department, the documents are stored for future reference, in case of an emergency situation.

TO-BE SITUATION

The data and documents extracted and drafted in the installation period are used only for diagnostics purposes and they are not required for any maintenance actions. For that reason the raw data files from the pre-install phase should be stored somewhere with restricted access to the interested parties, but should not be in the core application of the information system, since they will cause latency. Nevertheless, the material should be accessible by all the departments without special search of the information holder.

OVERVIEW

The main reason for using the system is to store information for later stages of the machine's life.

- ✓ Store files (mostly Word documents and excel files)
- ✓ Once per machine life

4.2.3 Preventive Maintenance Planner

Who: CS FF 2nd line Engineer – Preventive maintenance planner.

Why: To increase the machine's availability by optimizing the way maintenance is scheduled and executed.

What: The information that this case uses is:

- Layout parameters from inside the Fab area.
- Crane detail parameters.
- Local tool availability.

How: The AS-IS situation is non-existent for this case.

TO BE SITUATION

The PM Planner should be able to draw information from the system in a daily basis. For that reason, the two systems should be integrated and able to exchange information at any given time. In the latest version, the PM Planner will automatically calculate the optimized maintenance program, but the final command will be on the user who will decide the exact schedule, depending on the special circumstances of that given day.

The planner will have two functions. The first will be the initial plan with a future prognosis and the second the actual plan, which will be produced daily with the user engineer's intervention. In both functions the information from the system in hand should be available.

OVERVIEW

The main reason for involving this case is to withdraw data from the system and use them combined with other information, in order to plan an automated and more efficient maintenance plan.

- ✓ Everyday availability.
- ✓ Information should be updated or the user should be notified that the data are outdated and so he cannot rely upon them.
- ✓ The volume of the parameters is small.
- ✓ Integration with the PM planner is required (runs in JAVA and VBA)

4.2.4 Unscheduled downs – Diagnostics planning

Who: CS SE Diagnostics Engineers

Why: To create the diagnostics procedure and way of working for each location based on the infrastructure provided in every customer's facility.

What: Connectivity infrastructure map such as:

- EPS server version.
- Fabtop or laptop policy.
- Way of extracting data of the machine (service port or WIFI connection).
- Way of extracting data from the Fab

How:

IT-IS SITUATION

Currently, there is no standard way of handling this situation, in case a requirement for diagnostics emerges in different locations. The first and second line engineers located in the customer's site facilities are aware of the situation in the

Fab and the infrastructure provided, and they were called upon to create their own plan. With this situation at hand, two problems occurred. Firstly, since they are generalists, they don't possess the knowledge to implement the most efficient way of working on diagnostics procedures with the equipment handed, which resulted in low efficiency, in terms of time and success. The failure to identify the problem led to an escalation of the situation, with more specialized engineers to be called upon to solve the problem and cost even more to the company. Secondly, the third or fourth line engineers who are called upon an escalated event, had to figure out their own plan on how they would perform the diagnostics to each location, and what equipment they would need or would be able to use. This led to further frustration and crucial time consumption, which cost both to COMPANY X and the customer a great amount of money. For these two reasons, there is already a project in progress from engineers in CS Place X, who are trying to identify the situation in each connectivity infrastructure for each location, and create standard optimized diagnostics plans for each case. Currently, this team is flying all over the world to COMPANY X customers in order to achieve this. Unfortunately the situation in the Fabs changes rapidly and new systems are implemented or different policies are being followed, which will soon force the existing plans to be obsolete.

TO-BE SITUATION

Trying to improve the process of identifying the optimized way of working on diagnostics and eliminate the wasted time which is very costly, is not an easy task in an environment which interferes with such cutting edge technologies. Nevertheless, every step forward could have a huge impact on the company's image to the customers and assist to limit the costs and the wasted time during these actions. A useful step forward could be an information system, which contains updated information from the Fabs with respect to the connectivity infrastructure map, could be used, so the engineers responsible would avoid travelling to the locations and being informed for every update in the situation through the system. Then, the costs of travelling as well as wasting time to do so would decrease and the immediacy of the process would increase.

OVERVIEW

This case interaction with the information system is the extraction of information taken in the field.

- ✓ Connectivity infrastructure detail map
- ✓ Less than fifty (50) parameters
- ✓ After the first plan for each location then they should be notified for every change to create a new plan

4.2.5 Complex Upgrades

Who: R&D Mean Time to Repair Engineers (DE MA&I S&MT MTTR Repair & Recovery department)

Why: The purpose of this case is to create the best way to repair complex issues which lead to extreme longs downtimes and determine the specification needed to achieve them.

What: Critical parameters that should be in the Maintenance Requirements Manual (MRM) and IRM document such as:

- Fab layout parameters
- Crane specifications
- Move in requirements
- Storage facilities and capabilities

How:

IT-IS SITUATION

Currently, the information needed is not provided to the engineers who need it to plan the complex upgrades actions. To cope with that problem they have developed two solutions. They have created generic procedures depending on some basic crucial parameters on the customer filed, such as the crane height. For example if the crane height is over a certain point then the removal of the illuminator or the projection optic box can be achieved without the removal of their cell, which is the main body middle part of the machine, a huge part that needs a lot of hours to be removed. These generic procedures have been created without any knowledge of the actual situation, so the next step is to fly over to the customer's site and gather the information relevant to those basic criteria, as well as others details that could help speed up the process of every complex update separately.

TO-BE SITUATION

The engineers that have acquired the expertise on coping with complex upgrade planning, should focus on completing this task, and less specialized employees can deal with the tasks of gathering the information from the field. In addition, flying over is, as said before, expensive and time consuming for them, but they have no alternative in gathering the information from the field, since the local employees are occupied with other tasks. The efficiency of this process could be greatly improved if they could be provided with the parameters they need through the system in order to progress to the next steps of figuring better sequences for the complex upgrade action.

OVERVIEW

This case involvement with the information system is to extract information in order to improve the efficiency of complex upgrade planning.

- ✓ Layout parameters of the Fab and move in restrictions
- ✓ Small quantity of parameters
- ✓ Few times per year per facility
- ✓ Can afford for the system to be updated upon request

4.2.6 Future machine and tools redesign

Who: D&E several departments working on new machine development

Why: To create the next versions of the MACHINE X machine or the upgrades for the existent versions of the machine. Also groups within D&E have the responsibility to improve or redesign the special created tools that are being used to the Fabs for COMPANY X's machines.

What: Generic information from all the customers' Fabs with respect to:

- Layout parameters from the Fab and Sub-Fab
- Move in restrictions
- Infrastructure of Fabs

How:

IT-IS SITUATION

For most of the customer sites there has been no foresight for acquiring this information for this use. The members of these teams need to reach out to the rest of the employees to get the information desired. The only exception is one customer, which has initiated a project with COMPANY X's collaboration, and have a person appointed to provide data from the field.

TO-BE SITUATION

The desired situation would be for these employees to be able to find the information they need from the information system, which will be maintained by someone from the local crew of engineers.

4.2.7 Future process redesign

Who: CS organization and logistic department (GLS)

Why: Through the knowledge of the situation in the customers' sites, the related processes can become more efficient and accurate.

What: Generic information with respect to:

- Layout parameters from the Fab and Sub-Fab
- Move in restrictions
- Infrastructure of Fabs

How: The how analysis is identified as the same with the previous business case.

4.3 CONCLUSION

The results of the previous use case analysis were presented in this chapter. The results are information system requirements, which are going to compose the base for the design level of the system.

The concluded requirements will be divided in two parts. The functional requirements, which refer to the business functionalities we need from the system, and the IT requirements that will determine the system's needs in terms of hardware and software.

Functional requirements

- Store data and documents that are already produced by several working groups throughout the machine's lifecycle.
- Reinforce the current processes for obtaining the data.
- Create new processes to extract all the required data.
- Being able to retrieve the information produced from the customer sites for planning purposes, either via a GUI for use by a person, or by another system.
- Analyze the information to make a better prediction of the functionalities for the future machines and machine versions.
- The reliability of the information should be high.

IT requirements

- High security of the data, files and information are essential, since they concern clients' information.
- Ability to store data in form of parameters, layout drawings, raw data, and word files.
- The information system, even when the MACHINE X machines go to HVM phase, will have to handle low traffic volume of data, so the needs for scalability will be moderate.
- The parameters in question will be very specific about each machine.
- The possibility for transformation of the input data, parameters and files to meet the needs of the customers of the system.
- Communication protocols with other systems such as PM planner.
- Limited simultaneous users at the system.

5. FUNCTIONALITY SYSTEM DESIGN

This chapter will focus on creating the desired functionality system layout which is the second step of the project's methodology as can be seen in chapter 4.6. The processes through which the information system will work, the tasks needed for the system to properly function, and the roles that will execute these tasks are going to be established.

5.1 DATA FLOWS

Firstly, the complete system will be described by presenting the data flow diagram indicating the inputs and outputs of the system. Afterwards, an analysis will take place and key aspects of the diagram are going to be further expanded and described. The whole research is going to maintain a higher level, since the processes in very detailed levels are not established due to new requirements continuously emerging from the new machine introduction.

5.1.1 Data Flow Diagram (DFD)

The purpose of the data flow diagram is to demonstrate the flow of the information throughout the system. By this method the concept of the system can be more easily communicated to the stakeholders and interested parties of the project. The DFD is not a process modeling method and it cannot display timing of the events with respect to each other.

In this DFD diagram, four kinds of symbols are being used to describe states of the system.

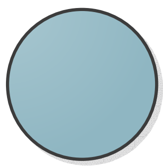
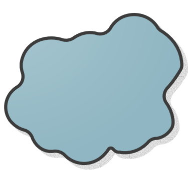
Symbol	Explanation
	The rectangular is being used for entities of the system, such as departments that are either providing information or receiving
	The circle is being used to describe that processes relative to the system are being performed.
	The parallel lines are being used to describe that data are being stored.
	The arrow is showing the direction of the information throughout the system.
	The cloud shape indicates the business cases which are intermediate nodes for the stakeholder departments.

Table 2 DFD memo

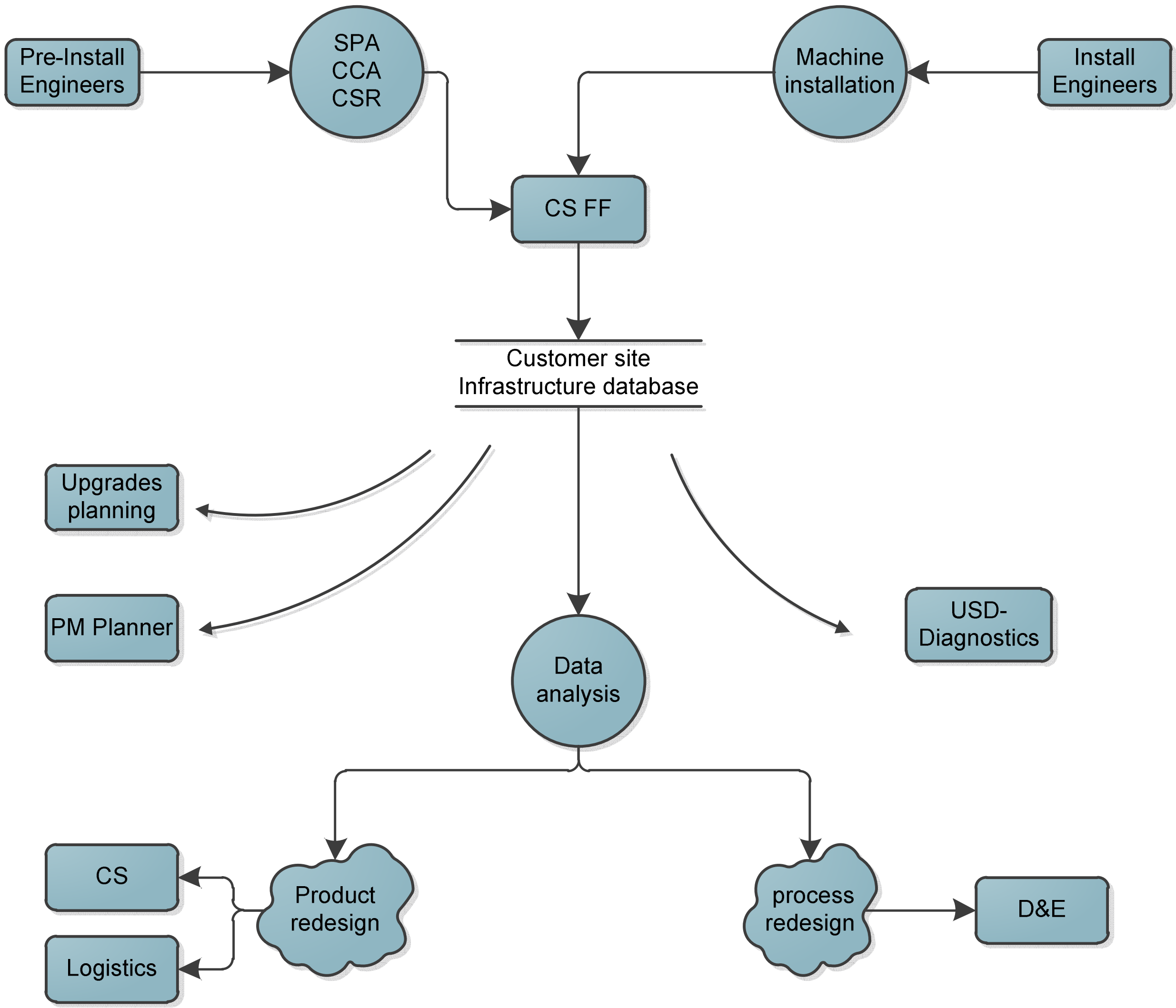


Figure 7 System's DFD

In the DFD is visible how the use-cases described above will be interacting with the system. The ones that will provide the information and the others that will use it to accomplice their tasks, with higher efficiency.

5.1.1 Data flow analysis

This diagram is based on the use-cases and on the following conclusions as for why the information should follow this design:

All inputs should flow through the CS FF department

This decision was made for several reasons:

- First and more importantly the only engineers that are close and have the most often experiences with the customers FABs, are the field factory engineers.
- Secondly, these are the engineers that must have access throughout all the life cycle of a machine, which doesn't contain their value only to a specific phase, such as the pre-install engineers.
- Thirdly, the engineers from specific cases have a temporary interest in the system. For example the pre-install engineers want to store their files, but don't really want to have tasks as to inform the cases that need to extract data.

The majority of the cases need to input and extract data, except of the business use cases that need to extract information

For that reason an application should be developed to analyse the data collected in previous phases of the system. The exact process or the specification of this application is out of the scope for this project.

An IT solution, which will store all the data that are being used, should be the centerpiece of the system

Due to the simplicity of the storage data this IT solution should be a warehouse database. The key characteristics of this database as well as its architecture will be analyzed in following chapter.

The PM Planner will have to extract the data autonomously

The PM planner will need the data at a specific form that would be integrated with its software architecture.

5.2 THE REQUIRED TASKS

In this chapter the analysis of the tasks to be performed for the correct function of the system and process need, which already have been identified in the previous chapter, are going to be presented. Based on these tasks, a proposal will be made for possible roles that can complete these tasks, within the standard organization.

After discussion and consideration with other colleagues, and by taking into consideration the use case analysis, the tasks that need to be performed are presented in table 3. Furthermore, in order for the appropriate roles to be identified in later stage, the specialization needed to perform those tasks is displayed as well.

TASKS	SPECIALIZATION NEEDED
Obtaining the data	Competency engineer
Insertion of the data	None
Updating the data	Competency engineer
Maintenance of the IT system	IT
Oversight of the process	Process owner

Table 3 Tasks and competencies

- Obtaining the data

  The information should be gathered by competency engineers, who possess the knowledge of the system and the infrastructure surrounding them, and have other tasks to fulfill at these locations, so they can be granted access easier.

  Four main separate areas have been identified at this moment considering the required data to be gathered:

  A. Fab/Sub-Fab Layout parameters

  The layout parameters would be gathered mainly through the SPA (site preparation audit), which is a procedure already in place. Some changes must be made in the data collection procedure, since the overall goal will be changed.

  Since the SPA and the crew who is in charge of completing it are focusing mainly on the IRM (installation requirements manual) the remaining data for the maintenance should be gathered through another audit that would be performed by the CS FF team of each site. This audit should be in accordance to MRM (Maintenance requirements manual), which is a document still in progress and those two actions could be developed side by side.

B. Connectivity map & Infrastructure

The connectivity map for the engineers inside the Fab, and the infrastructure they possess in there in order to complete their tasks, should be logged by someone with the expertise and the competency to realize the small differences. Mistakes in obtaining correctly this information could lead to problems downstream in the process.

C. Move in constraints

The move in constraints will be gathered by two sources with respect to their nature. The constraints that are related to the layout of the customer sites, such as move in corridors width and elevator dimensions are already being acquired through the SPA. The time-related constraints, such as the day that COMPANY X is allowed to import equipment and parts inside the customer Fab, will be acquired either by the logistic department, or by a CS field engineers who will be responsible to communicate with the customer to get briefed about this kind of information.

- Insertion of the data to the system

For this task, there is no specific description for the qualification of the person who will be responsible. This person should be a generalist and his task will be mainly to extract data from mock documents that the engineers from the fab have created. The reason this task is required is the confidentiality barrier that exist in between the Fabs and the outside world, making an implementation of a unified system impossible.

- <u>Updating the data</u>

The data that exist in the system will never be reliable unless there is an updating mechanism that will ensure the credibility of the information given. Depending on the cost and the response rate users need to extract from the system, the information system can have an update after request scheme or constantly keep updating. The second choice is more expensive, since there should be someone always engaged with this task.
Because of the low rate of changes that will happen in the future, the stakeholders agreed that the first model should be implemented.
The changes that can happen to any of the above mentioned categories of data could be round up to two different cases:

A. <u>Changes performed by customer</u>

In this case the person who is responsible to communicate with the customers in the Fabs, should be responsible for each location, to retrieve this information from the client.

B. <u>Changes performed by COMPANY X engineers</u>

All the COMPANY X engineers, that perform action on the machine or the surrounding, should be notified to record the changes they make in the environment of the machine. That way the changes will be identified and logged into the system without the need for unnecessary actions.

- <u>Maintenance of the IT system</u>

The maintenance of the IT system will fall directly and in complete to the IT department, which in conditions could create the whole system as well.

- <u>Oversight of the complete process</u>

Due to the way of working in COMPANY X, all the processes have a process owner. He is responsible for the fluent operation of the complete system, and supervises the changes and the upgrades that are necessary for the system.

5.3 ROLES

Having clarified the tasks that the new process under investigation would need, the next step was to identify the roles responsible for executing these tasks. After discussing it with my mentor, we reached to the conclusion that firstly we would try to match existing roles to the tasks, because of the nature of the project, that wouldn't allow the creation of new roles until the project was at an implementable level.

Following his advice, we started exploring the current organization roles and tasks and only if we couldn't match the tasks to the existing roles we would go a step further, to creating our own role with description of tasks that should match the company's organization.

5.3.1 CS organization structure

The CS organization consists of three departments. The NPI & NTR, which is responsible for new product initiation, the HVM department, which is responsible for the functional machines at the customers' sites that are already in the HVM phase and the third one is the FF (field factory), which is responsible for the human resources that are occupied mainly inside the customers' facilities.

Initially an investigation was made through the corporate site to identify the standardized structure of the roles on the field. The following diagram was a result of this research, and shows all the identified roles that either already exist or COMPANY X would like to exist in every customer site.

The first approach we had was to explore the site and Fab buckets, but soon we realized that they were operational buckets and they had no tasks similar to the projects at hand. The next step was the project / improvement bucket, but still we found that the tasks had no similarities with the tasks we were searching for. Finally we decided to have a meeting with the owner of the document to learn more about the exact tasks of each role.

After the meeting we had with an operations analyst of CS who is trying to standardize the roles to every customer site and is responsible for the diagram for the past two years, he explained that the engineers from FF department actually do the majority of the work in almost every action. He then proposed that we extend the investigation towards this department in order to find the suitable roles, and provided us with several key employee names from the major customers' sites.

During the communications with the employees from the field, we realized that only one site has created a job with similar features to our tasks, without this role being yet in the standard organization, in order to accomplice better results in another project called SEED (Supplier Equipment Engineering Data). This is a role that is under consideration for becoming a standard role with his tasks being to collect data from the surrounding of the machines for R&D purposes.

5.3.1 Involved Organizational Roles

There are two proposed solutions for this problem. The first solution is an attempt to use more the company's existing resources. Moreover the second one will introduce the features of employment of a new employee to fill in the needed role.

As was introduced in the previous chapter, the key employee that could be executing the two major tasks is the SEED coordinator engineer, with the assist of a Project Leader who will be responsible for the install phase. The PL responsibilities will be to ensure that the data are gathered in the correct form and they are forwarded to the person for recording them to the system.

TASKS TO BE PERFORMED	ROLES TO EXECUTE THEM
Obtaining the data	SEED coordinator engineer/ Install PL
Insertion of the data to the system	Field administration
Updating the data	SEED coordinator
Maintenance of The IT system	IT department engineer
Oversight of the complete project	NPI PL

Table 4 Roles proposal solution one

In the second solution, where the SEED project employee cannot provide us with the data required, and since the research for identifying another role that could suit our needs was not as very successful, we decided that a new role should be created. This new role should be a HFE (half time employee) or a FTE (full), but only half of his time should be appointed working for this system, since the needs for this system aren't that demanding. The need for an employee with these features is only for the customers who are using the machine for manufacturing and not for research, where the number of the machines is usually small.

5.3.2 Pros and Cons for each solution

The pros and cons are displayed for each solution in the table below. The decision for which solution must be followed is up to the company and the PL responsible, and they have to take into account all the facts for each case.

	Through existing roles	Introduction of a new role
PROS	Greater efficiency of the human resources	Updates to the system can be performed in regular basis
	Adapting to the current organization	No disruption of the current human resources tasks and routine
CONS	Updates should be performed upon request	More human power to complete the same tasks
	More workload for the existing staff	Interruption of the current way of working by differentiating the current structure

6. SYSTEM ARCHITECTURE ANALYSIS

This chapter will explain the information systems that are currently used in COMPANY X.

Information system architecture is a fairly young research field. Most literature was written after the year 2000. The goal of information system architecture has been captured by Vasconcelos et al. (2007):

Information System Architecture (ISA) addresses the representation of the IS components structure, its relationships, principles and directives (Vernadat, 1996), with the main propose of supporting business (Garlan, Allen, & Ockerbloom, 1995).

An information system architecture is comprised of applications, enterprise integration patterns and databases. The applications are the information systems that process the data in a way that supports the business goals. Certain applications can tap into databases to extract the required information. It is also possible for the applications to communicate with each other. For this communication, integration patterns can be used.

It is important for the information system architecture to be aligned with the company's structure. Different patterns can be used to connect different information systems. If this is done in a way that is not optimal, all information systems might operate slowly or data errors might occur. If the rules from the literature on information system are applied correctly, the information system will run smoothly and the existence of data errors will be low.

6.1 ENTERPRISE INTEGRATION PATTERNS

There are many ways in which information systems communicate. This is done via enterprise integration patterns. Hohpe and Woolf (2004) made a classification of all available patterns. They distinguish sixty-five types which are divided into four main categories.

6.1.1 File Transfer

File Transfer describes a form of communication where one application creates a file that can be read in a later stage by another application. When using this pattern, formatting is a very important issue. It is very rare that the output of one application is the exact input for another. Therefore processing and standardization tools are required. For this reason standard file formats have emerged and grown in usage. The three most commonly used formats are COBOL, UNIX and XML.

A downside of File Transfer is that files cannot be used at the same time. Also the processing of files can take a considerable amount of time. For these reasons File Transfer is normally used in a regular business cycle (nightly, weekly, monthly etc.). This means that each application can only read or write the file during its designated time frame in the cycle. Arguably the biggest downside of File Transfer is that applications can be out of sync during the business cycle. Since there is no direct connection between them it can take time for updates to be transferred to another application. Until this has happened the application will run on outdated information.

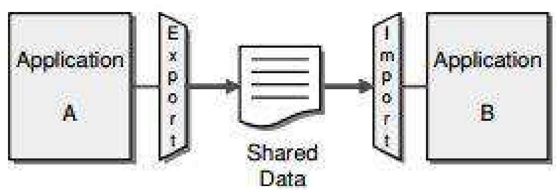


Figure 8 - File transfer

A major upside of File Transfer however, is that applications can function completely independent of each other. The developers of one application do not need any knowledge on the internals of another. The only necessity is concession about the contents and storage location of the transferred file. This allows for a nice decoupling of applications, which is very useful when applying modular design principles.

6.1.2 Shared database

A way to overcome the limitation of File Transfer regarding the synchronization of applications is using a shared database. A shared database ensures consistency between applications at all times. Since a shared database can be used by different application at the same time there can be conflicts when simultaneous changes are made to a single piece of information. However, transaction management software has been introduced to solve these conflicts smoothly.

A great contribution that made shared databases more popular is the introduction of SQL. Most databases run on this technology. This solves the problem of multiple applications requiring different file formats.

One of the biggest challenges of the shared database technology is the design. For a database to work it needs to be organized in a way that each application can easily extract its required information. This information needs to be clustered within the database. However, applications can require a different clustering. These are issues that cause a lot of difficulties during the design of the database. The same problem occurs when a new application is introduced or when databases have to be merged, due to for example a company takeover. In general, shared databases are very rigid and inappropriate for dynamic information system architectures.

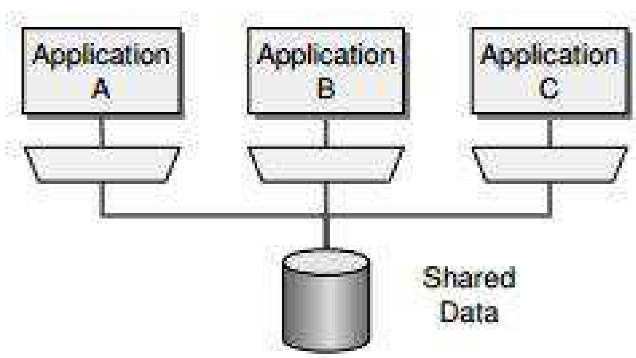


Figure 9 – Shared database

6.1.3 Remote procedure invocation

The File Transfer and shared database patterns both can be used for sharing data among information systems. However, sometimes raw data is not enough. An action from one application might need to trigger an action from another application. Also one application might require data that needs to be processed first by another. For these situations the remote procedure invocation pattern can be used. This pattern allows an application to call another, ask it to perform an action and send back the result. In this way a strong modular design can be applied. Each application handles its own data, but its functionality can still be used in other applications. This way of working ensures that applications are always in sync and multiple applications can be active at the same time.

A number of technologies to enable this pattern are available such as CORBA, .NET, and Java RMI. Also SAP, one of the most widely used ERP-software packages, uses this technique. In SAP, many internal transactions exist that call and process internal data. Many of these transaction functions can be called remotely. These are known as Business Application Programming Interfaces (BAPIs).

The major downside of the remote procedure invocation pattern is that it can slow down the architecture as a whole. Each remote call takes up more time and processing capacity than reading a database. If the entire architecture is coupled with remote procedure invocations the performance will decrease when the architecture gets more and more complex.

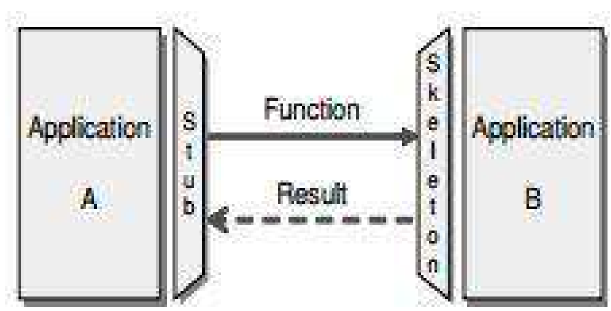


Figure 10 – Remote procedure invocation

6.1.4 Messaging

The messaging pattern makes use of a message bus to connect applications. The message bus is a standardized medium to transfer information. This is very similar to the File Transfer pattern, but messaging allows connections between more than two applications. Also, while the File Transfer pattern can only be used to exchange data, the messaging pattern can invoke functions within another application. Messaging does however suffer a little from the same delay in process time. This is solved for the most part because the bus allows for small, regular chunks of information. Also the user of the application that is sending the data request does not need to wait for the other application to respond because both systems do not need to be active at the same time. For this reason messaging does not slow down the information system architecture as much as remote procedure invocation patterns. Another benefit of the message bus is that it can be extended when new applications are added. No adaptations to the existing applications are necessary.

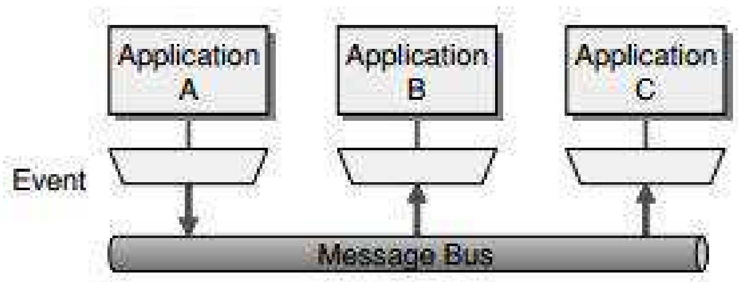


Figure 11 - Messaging

6.1.5 Conclusion

In information system architecture all the discussed patterns have a place. Each pattern can fill a specific need. However, generally the most used pattern at COMPANY X is the messaging bus. This allows for relatively fast coupling of the applications while still allowing for a modular and flexible design.

6.2.1 Databases architecture theory

Currently, there are several options for making a database's architecture. In the following section an overview of three main categories and sub-categories of database architectures will be presented, together with the advantages of each.

<u>Application Logic</u>

The way application logic is distributed within the system distinguishes the database architectures. Application logic contains the presentation logic, the processing logic, and the storage logic.

The presentation logic takes care of the format and presentation of the data on the screen of the user. Processing logic handles data processing, taking into account the business rules and data management logic. Finally, storage logic controls the storage and retrieval from the hardware.

Identifying the tier(s) that these logics are processed on can lead to determining the type and subtype of architecture we are facing.

One-Tier Architectures

One-tier architecture allows only a single server or platform to contain all the required components for a software application or technology. An example of a one-tier database architecture is when a program runs on the user's local machine, and references a file that is stored on that machine's hard drive, thus using a single physical resource to access and process information. The same file could also be stored in a group database in a shared location on a single machine. In that case multiple people with the use of an interface package could load the data and then process it on their local computer.

Another type of one-tier architectures is mainframe computing. Mainframe refers to a central data repository, in a corporation's data processing center, that communicates with users through devices like workstations or terminals. Although this is clearly a client-server system, it is considered one-tier architecture, because all of the processing power is on a single machine.

The benefit of one-tier architectures can be seen in the cost related, which is relatively low compared to other architectures, and to the low complexity. Therefore, it is suggested for a single or a few users and when small amount of data is considered.

Two Tier Client/Server Architectures

Two-tier architecture contains two layers, a data layer or data structure that gets stored on a server, and a presentation layer or interface that runs on a client. This approach enhances the scalability. However, it does not divide the application layers so they can be utilized separately. This makes them difficult to update.

Two-tier architecture is the architecture most of the computer users are familiar with, at the moment. The basic web model is an example of a two-tier architecture. A web browser makes a query to a web server, which then processes the request and returns the desired response, which is the web page.

Two-tier architecture is beneficial when scalability is essential but causes problems with regards to updating since there more layers that need to be updated. Therefore it is suggested for a relatively small number of users on the system (100-150).

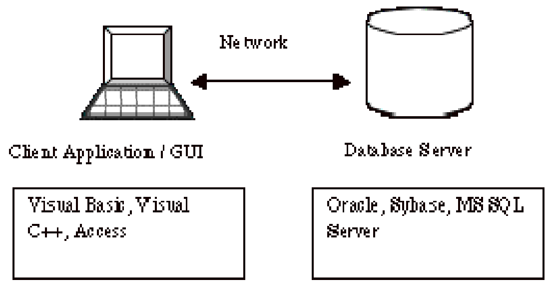


Figure 12 Two-Tier Client-Server Architecture

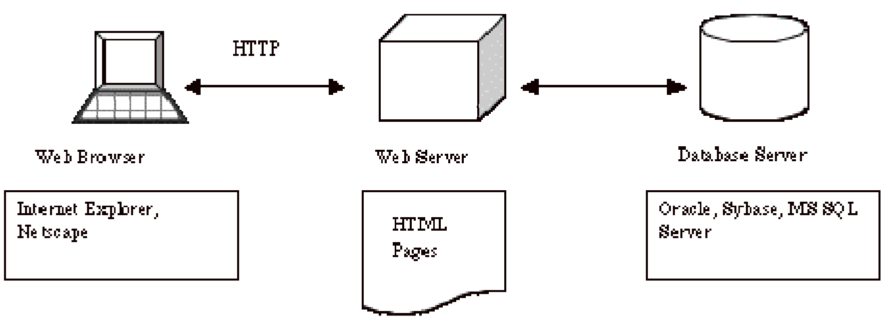


Figure 13 Web-Based, Two-Tier Client-Server Architecture

N-Tier Client/Server Architectures

N-tier database architecture mostly exists in a three-tier configuration. The three-tier architecture is an extension of the two-tier where an additional middle-tier/business-tier is included in the client/server model. The business-tier is an application server that incorporates the business logic, and it is used to take up some processing from the client and server components, by translating client calls into database queries and translating data from the database into client data in return. As a result, the client and the server have no longer direct communication with each other.

A web-based application can also have an n-tier architecture. The multiple-tier architecture is more scalable than the two-tier architecture. Additionally, every layer of the n-tier architecture can be upgraded or even completely changed separately from the rest. That makes maintenance easier and it allows flexibility.

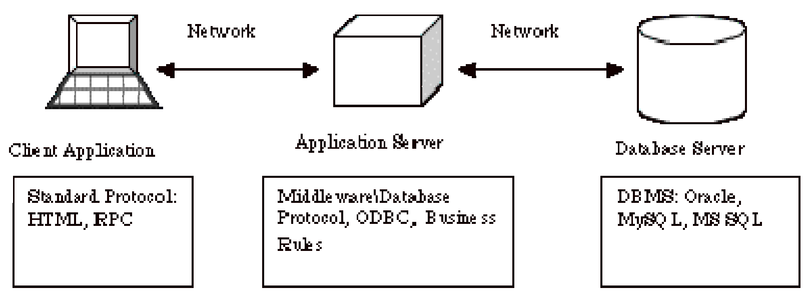


Figure 14 Three-Tier Client-Server Architecture

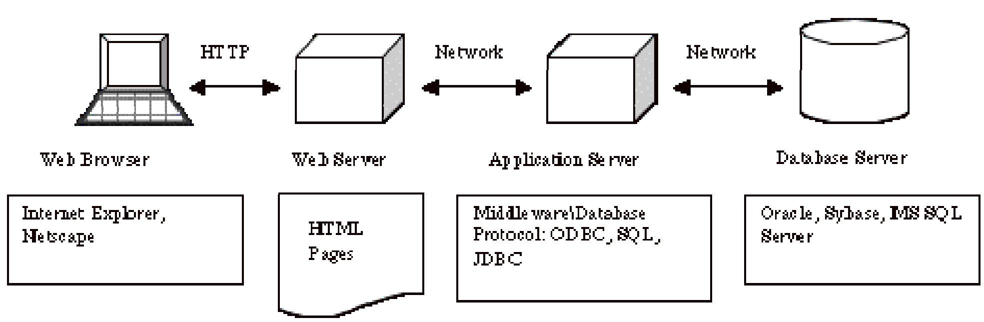


Figure 15 Four-Tier Client-Server Architecture

6.2.2 System architecture possible solutions

The complexity of the complete system is quite high, but the needs in terms of IT are limited. Therefore, a variety of solutions will be presented with their advantages and disadvantages. The system's solutions of the next chapter will be based on those architectures.

The reason for investigating the system architecture is to provide a guide to the IT department in case the company decides to create the system in-house. For that reason and to avoid possible mistakes in architectures, we are not going to analyze a N-tier client-server architecture. The solutions given in this chapter will be focused on the simple one-tier and a little more complicated two-tier architectures.

One-tier architecture solution

The first solution could be a one-tier architecture solution. This kind of solution has a lot of disadvantages, but it is cheap and can provide functionality to the system. It can be integrated with several existing systems and could be realized through existing systems as well.

This kind of architecture would fit our problem, because the handling of the data is happening on the CS offices at the customer sites. This means one entry point per site, which makes it possible to implement a database file in a single computer and distribute to the other stakeholders through a shared location. Each location would have its own file and a special space for this system in the shared server. The system would communicate with the other systems through the file transfer method, which means that the file created should be readable from the other systems.

The negatives of this solution are the limited functionalities as well as the inadequate scalability. The data of different form would have to be placed in different files and the users could not be notified for any changes, except if the intermediate server had such functionality.

Overall there are not a lot to say about this kind of architecture, since it is simple, and the goal that fulfills is to obtain a cheap, easily created solution that will only focus on solving the major requirements.

Two-tier architecture solution

In a solution with two-tier architecture, the main difference is that the clients will not have access directly to the database, but they will have to go through another application.

In a two tier architecture more than one person can have access to the system; however there is not very large elasticity for a very big number of concurrent users. The complexity of the system is increased compared to a one tier architecture system but still not enough to be an expensive system to create.

A possible two-tier architecture is depicted in the following diagram. Due to the requirements of this project, and the variety of the formation of data that need to be stored, two different storage systems have been elected as optimum solutions.

The two storage systems will communicate through an application which will be also responsible to present the data to the clients. The first one should be a database, with a relational format, and the second one will be a plain server for storage purposes. In the database the parameters will be stored and the addresses that the application can find the related files in the server for each entity.

The files that will be stored in the server will be related documents that each use case needs to store, such as the word documents and the raw data. By this method the expensive database will only have to store valuable parameters and addresses for the application to reach the rest files, which will also improve the speed of the database's operation.

N-Tier architecture solution

As mentioned above, due to the complexity of the three-tier and n-tier architectures, there will not be an investigation for possible solutions. Nevertheless, for the correctness of the investigation, ready-made solutions will be investigated in the next chapter, and they are going to be selected by weighing the similarities of the features they provide with the requirements of the project.

7. IT SYSTEM SOLUTIONS

This chapter will display the information technology solutions that were found suitable to satisfy the requirements raised in this project which is the third step of the project's methodology, as can be seen in the diagram of the chapter 4.6.

Initially the solutions will be presented according to their architecture complexity, which goes together with costs for creation or purchase and integration. Afterwards the solutions will be compared to each other in order for the company to obtain a clear view on which IT solution fits best the organization, and the budget that will be set for that purpose.

7.1 SOLUTIONS BASED ON THEIR ARCHITECTURE COMPLEXITY

After the analysis of the IT systems architectures had been completed, and the current layout has been mapped, the idea of proposing ideas from all the specter of systems complexity has emerged. Since the project has been seen as merely significant to some people and substantial to other, having a variety of solutions that could fill the different needs, seemed like the best choice to keep their interest active.

The first group of solutions will be simple, oriented to cope with the basic requirement, which is the storage of the information that will be acquired through the new initiated processes. The storage together with the communication of the information are the major functions the stakeholders asked for, and can be accomplished in very simple and costs effective ways.

However, the first group solutions will have lot of disadvantages, especially regarding the performance and capabilities aspects. For that reason, a solution with more complexity, that translates to higher development and maintenance costs, at least considering the IT system itself, will be presented. For this group as well the in house system built method will be chosen, since the advantages it provides are far greater than the disadvantages.

At last, some all-around solution from big firms will be presented, that would be more expensive and with increased complexity, but the capabilities and the possibilities for extended functionalities might appear more appealing.

7.1.1 One-tier architecture solutions

The one-tier architecture doesn't allow for flexibility and creativity concerning the different solutions that can be proposed.

As mentioned in the previous chapter, the system will be working through a shared company server, already in place. The parameters will be stored in a structured file and the rest of the data will be stored directly as files in the designated space for each specific entity.

The decisions that need to be made for developing the IT system are the following:

- What file format should the structure file that will contain the parameters have?
- In which already in place shared server of the company's should the files been stored?
- Which is the entity that will store the files?

Considering the requirements and what has been agreed by the stakeholders, the first question that should be answered, is which entity should be the focus point of the system. The answer to that is that the machine should be the main entity, since the whole purpose of the customer support department is to provide higher machine availability to the customers. This decision leads the system to store all the relevant files per machine under one directory in the server, named after each machine. On the other hand, the possibility for multiple entries of data per site is possible.

The next topic investigated was the file format of the structured file. This structured file will be the one containing all the parameters and the information needed for planning actions at the field. The rest of the files will contain further information stored as raw data or layouts that are relevant to the machine, but do not pose first priority in information extraction for planning.

The first proposal for the file format is an excel file. This is easy to create, easy to alter and almost everyone is familiar with it throughout the company. In addition the .xml files that excel generate can be integrated with the majority of the other IT systems and the relevant information can be extracted from those files. The negatives of an excel file are the very small scalability it provides, narrowing it to one user per time. Also, since the data are not linked to each other through a proper structure language, integrity issues might concern the users.

For this simple case, after the mentor's advice, a prototype structured file was created. The purpose for this file was to demonstrate to the stakeholders how the core functional requirements are being fulfilled, and to engage them by attracting their interest through something tangible. In addition, by using this prototype in meetings with them, some minor requirements were relatively conceived in an easier way.

Another solution could be a database file, which means a file structured with SQL language. The most popular are the ACCESS database files which are also available throughout the company, by Microsoft Office. This solution is harder to create than a simple excel file, since the creator needs to have some experience with access development or more broadly with SQL. However, the creation of this kind of file will not be a challenge for the IT department. The advantages this solution offers in comparison to the excel file is the structure provided through the SQL language, which enables the possibility for queries. Using queries can improve the effectiveness and the efficiency of searching data inside the database, as well as assisting in processing these data to accrue valuable results.

However, by using an access database, the possibility for easy altering the format of the file is lost. In order to cope with this problem, a more thorough planning of the file should be done, before starting to use the file for operational use, in contrast with the excel file that can be developed in parallel, according to the emerging needs.

With respect to the servers that could host the system, two solutions where found suitable. The first one is the Microsoft SharePoint server, which was recently implemented in the company. Lately, the company follows the strategy that all the files that are to be communicated between employees and don't belong to one of the other embedded systems, should be stored in the SharePoint. SharePoint offers a lot of features such as control access to the files, which assists towards eliminating the security issues. Additionally, SharePoint can notify the users for changes on specific files, which is useful for controlling the files and the occurring updates. The disadvantage of using Microsoft's system for storage is the limited storage provided for each site. SharePoint is stored in Microsoft's servers, which makes them expensive for the company.

Another solution, but with less functionality on the GUI is the TCE database server. TCE is being hosted in the company's server, which makes the files both secure and cheap to store. The downside as mentioned above is the limited functionalities of the GUI.

The table below demonstrates a summary of the possible one-tier architecture solutions.

Problem	Solutions	
File format	EXCEL file (.XML)	ACCESS File Database
Server in use	Microsoft SharePoint	Siemens TCE (Teamcenter)

Table 5 One-tier architecture solutions

The one-tier architecture solutions are cheap, simple to create and implement, but have a lot of disadvantages, with major being that each site and each machine has separate files. The problem stated, makes very hard, if not impossible, to process the data in a holistic view and use them for R&D and process improvement purposes. Also, it creates a lot of duplicate data that are occupying extra storage space, which translates to wasted money.

7.1.2 Two-tier architecture solutions

In the two-tier architecture system, all the different customer sites data will be included in the same integrated system, stretching the capabilities for possible uses of the information.

The solutions of this section will be using the architecture introduced in the previous chapter. An extensive investigation has taken place, in order to identify if newer technologies in the database section could improve the database, by storing all the data in one server under the database umbrella. Several solutions have been identified under the NoSQL databases.

NoSQL databases, such MongoDB, Maria DB and couch base, are databases that do not use SQL language, or at least not only SQL, to structure and perform the queries. It is a new trend that enables broader functionalities for storing data.

Nevertheless, NoSQL databases were rejected for this project, because of two reasons. The first one was the recent leakage of data that happened to MongoDB, one of the largest NoSQL databases, which raised the alarm for the security standards COMPANY X wants to maintain considering customer data. The second reason was the inexperience of the staff to this new model of databases, which would translate to additional costs for educating staff or hiring new personnel with expertise in the field.

Since NoSQL schemes were out of the picture, the former architecture, with one database structure server and another physical server for storing all the other files would be the stepping stone of this investigation.

After multiple considerations and discussions with IT staff employees, the most suited program concerning costs, efficiency and employee expertise is a DBMS (database management system) based on Microsoft SQL server. The reason, as the experts stated, is that the company has already acquired many licenses for SQL server that could also be used in the development of this system.

The DBMS would work with a front-end system that would communicate with two back-end components. The database server would be communicated through SQL language, while for the plain server the files will be invocated through the directories that will be stored in the database. The front-end component will also have a GUI, for direct use of clients, but will be integrated to the PM planner, which is one of the main requirements.

This kind of system enables future integration with other systems, which might be developed to advance the planning procedures at a later stage.

7.1.3 Ready-made complex solutions

Even though a functioning solution, which can theoretically fulfill the requirements emerged in the previous steps of this document, has already been found, there are still a lot of benefits that can be harvested by using a more advanced and complete system. Advanced functionalities and increased system architecture methods can improve the overall performance of the system and the output that is attributed to the company.

When it comes to more complex architecture solutions, the choice made for this project was to investigate outsourcing the development to a software development company or to investigate through ready-made solutions.

Due to the conceptual base of the project, there was no possibility of giving out an official system request document from the company, requesting details with respect to the product each company had to offer. This created difficulties in both directions that this project could follow, but also made the software development companies hesitant to engage and spend resources. The only possible way to go from there, was to research through the ready-made solutions, by trying to match their features to the requirements of this project.

When I initially started the research for ready-made system solutions it was like swimming in an ocean. The different fields and aspects of the information systems and the huge amounts of technical terms, made the research challenging. My thoughts were that it would be impossible to find a program that would have similar features with the requirements of this project.

Eventually, after several discussions I had with colleagues that also work on relevant fields, the idea to explore more the product lifecycle management (PLM) systems emerged. The reason was that ultimately the project was about keeping track of the product's environment with the purpose of increasing its availability.

Figure 16 Product Lifecycle Management platform (plmnews.egyptplm.com)

A PLM system is a very broad system that engages with a lot of aspects of a company's management and consists of a lot smaller, more on the point components. One field that PLM systems are engaged with is the maintenance of the machine, which is highly influenced by the machine's environment.

Taking that into account the next step was to identify which component of the PLM system would be compatible with the functionalities that we our seeking from an It system solution.

The investigation led me to Enterprise Asset Management systems (EAM). EAM is about tracking and managing the costs associated with asset lifecycles. As IBM explains, managing service contracts, spare parts, workforce, asset performance levels, procurement, asset deployment locations and other physical asset-related characteristics in the most cost-effective way possible is the goal of any EAM program. So the research focused on identifying the strongest EAM systems in the market, which match with our requirements.

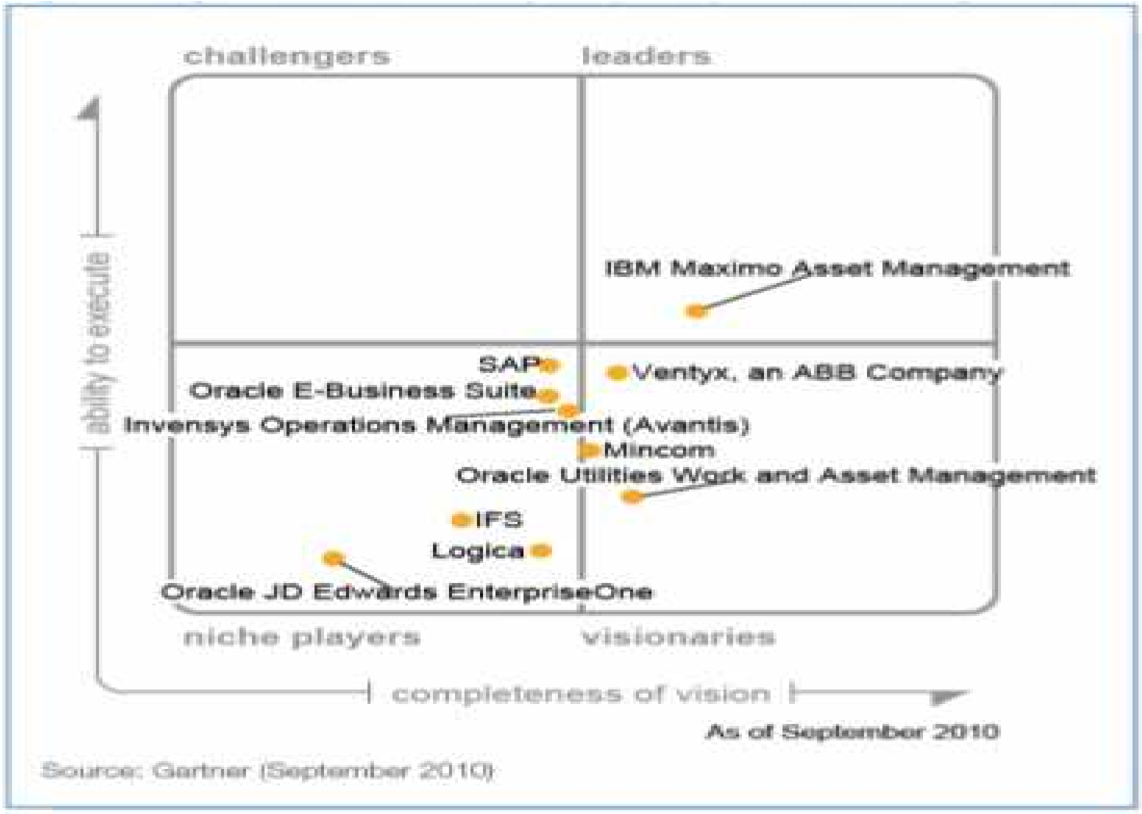


Figure 17 Magic Quadrant EAM (Gorczynski, 2012)

As can be seen in the diagram in figure 27, IBM Maximo has a real edge when it comes to asset management. Nevertheless, since the company is already working with SAP, and has a plan for transitioning to SAP HANA in the near future, we decided to focus on these two systems.

IBM Maximo Asset management component

The main features of the IBM Maximo Asset management modules, as they are presented in their website are:

- Asset management – Achieve the control you need to more efficiently track and manage asset and location data throughout the asset lifecycle.
- Work management – Manage both planned and unplanned work activities, from initial request through completion and recording of actuals.
- Service management – Define service offerings, establish service level agreements (SLAs), more proactively monitor service level delivery and implement escalation procedures.
- Contract management – Gain complete support for purchase, lease, rental, warranty, labor rate, software, master, blanket and user-defined contracts.

- Inventory management – Know the details of asset-related inventory and its usage including what, when, where, how many and how valuable.
- Procurement management – Support all the phases of enterprise-wide procurement such as direct purchasing and inventory replenishment.

Obviously, not all of these components are relevant with this project, but the first one could become, after a customization, the component to use in the stated situation. Moreover, if the company chooses to go for a complete solution like this, then the rest of the components should also be engaged in the operation per site. By this, they could have a complete solution for managing each customer site, through one IT system. (Maximo Asset management, 2016)

SAP Asset management component

The SAP component would be extremely valuable to the company, because it is possible to integrate it with the rest of the SAP components that currently the company relies on. It would be a smooth step towards the future mode of operations of the company, which focuses on unifying a lot of systems under the SAP HANA umbrella.

The main features of the SAP Asset management module, as they are presented in their website are:

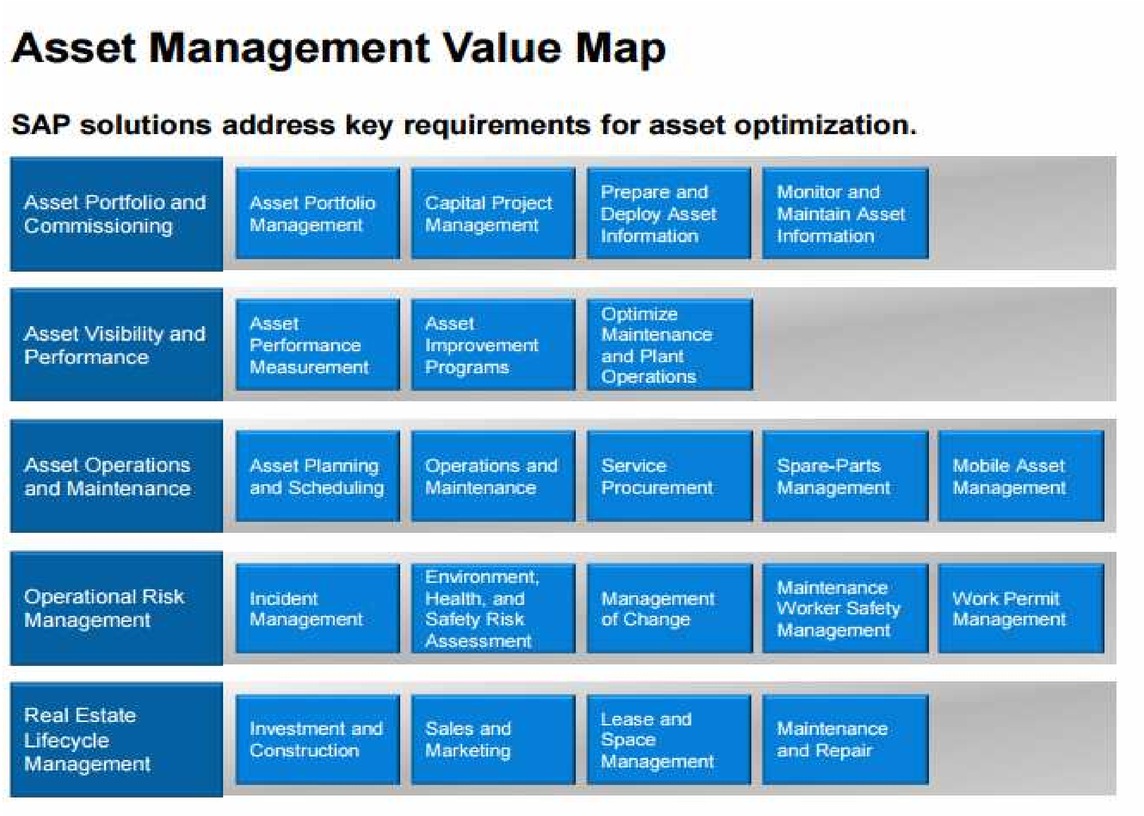


Figure 18 SAP Asset Management modules (SAP WebSite)

Once again, the system is way too complicated for the intended use, but the choice of a ready-made complex system should be made with the goal to implement different processes under an integrated IT solution. The module that suits to the project's use is the "Asset Visibility and Performance", which is demonstrated again through the SAP site in more depth. (SAP Asset management)

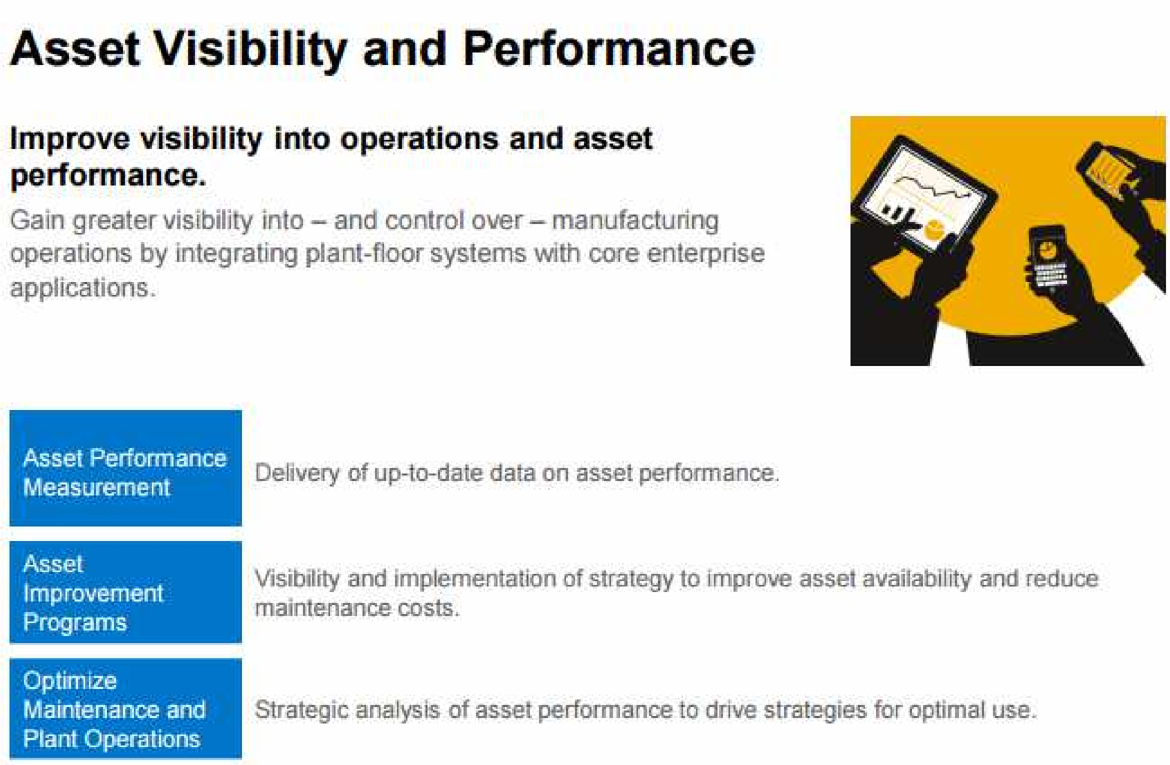


Figure 19 SAP Asset management selected module (SAP WebSite)

7.2 SOLUTIONS COMPARISON

This research's goal is not only to present some solutions that can cope with problem analyzed, but to select one of them as the most suited, regarding the requirements presented in the initial analysis. However, because the project is in a conceptual phase, the significance of some of the criteria on which the comparison is going to be performed, are being shaped using assumptions. If the company decides to implement one of the solutions, the comparison should be reviewed with up-to-date parameters.

7.2.1 Key indexes that will be used for comparison

In order to achieve a meaningful comparison, one of the most significant tasks to complete is to recognize the parameters on which the comparison is going to be based. For this comparison the parameters will be classified in five main categories.

These parameters describe the functionalities that we meet in IT systems and they will be signified with respect to the functionalities that have been identified in a previous step.

The five main categories are:

- Costs
- Security
- Capabilities
- Usability
- Maintainability

The costs mentioned refer to:

- Cost of creation / purchase,
- Cost of implementation,
- Cost of customization and,
- Cost of maintenance

Security is taking into account the safety of the data. This category is extremely important to this case, due to the sensible data that are being handled. The elements of security are:

- Data storage safety and
- Users accounts control

The third category refers to the capabilities of the solution. This is further analyzed in:

- Availability of the system,
- Compatibility with other systems,
- Credibility of the system,
- Maturity of the solution,
- Extensibility,
- Flexibility to transformations,
- Scalability,
- Reliability

The usability is concerned with the ergonomics of the solutions. This is further broken down to:

- Learnability, which is the ability of the users to get acquainted with the system,
- Manageability/change control
- Traceability of the changes to the data, as well as to the system
- Understandability/ ease of use

Lastly the maintainability will be further expanded through the following parameters:

- Durability
- Efficiency
- Robustness
- Upgradeability

7.2.2 Comparison results

The comparison will be executed based on the previous presented indexes. Initially the appropriate weight will be given to each index with concern to the significance that this index has for the current problem. Then each solution will be evaluated on those indexes, displaying which solution will be finally proposed.

The rating will be made in climax that can be seen in the table below. Every parameter is being attributed to a factor in order to calculate the final results.

Parameter	Factor
very high	1
high	0.75
average	0.5
low	0.25
Very low	0.1

Table 6 Parameter-Factor table

For the costs in specific, the high factor will be a positive one, which means that low cost is more important and as such it will be rated.

The thorough analysis can be seen in appendix A, where all the solutions are being compared with all the indexes. The overall comparison has concluded in the proposal of one solution, as the most suitable for this specific situation. As is shown in the table 8, the final solution is the one with a file transfer management system, and a Microsoft Access database file structure.

Key Characteristics	Importance for project	EXCEL SharePoint	ACCESS SharePoint	EXCEL TCE	ACCESS TCE	DMBS	IBM MAXIMO	SAP
Costs	High	Very High	Very High	Very High	Very High	Average	Low	Low
Security	Very High	High	High	High	Very high	High	High	High
Capabilities	Average	Low	Low	Low	Low	Average	High	High
Usability	Average	High	High	Average	Average	High	High	High
Maintainability	High	Average	Average	Average	Average	Average	High	High
OVERALL	-	0.475	0.475	0.45	0.5	0.425	0.45	0.45

Table 7 Overall solutions comparison

This solution has two main features that distinguish it. The first one is the security, which as was previously stated, is one of the main concerns, and by this solution it is handled very well. The second one is the simplicity of the system that is tangled with some aspects of the efficiency of the database solution.

8. CONCLUSION

8.1 GOAL OF THE PROJECT

The goal of this project was to get engaged with an issue that has recently come to several people's attention. It was not targeted though to provide a solution, but to impersonate what a possible solution could look like. The company would like to use this research to evaluate whether there is a possibility to improve by engaging in finding a solution to this problem.

The projects overall comes down to three main objectives. The first one is to raise awareness about the specific issue that has been noticed by a few employees. Until recently that the main business focus was on the previous machineries, there was no need to focus on the environment of the machines at the customers sites. However, the new machine is way too complicated, which forces the process of improving its availability, to consider more multi aspects solutions. Nevertheless, people do not like changes unless they are necessary, and the aim of the project was to demonstrate why it is necessary to consider this issue as an important problem.

The second objective of the project was to analyze the situation and come up with the requirements of the system to solve the problem. The analysis was made by investigating all the engaged parties and actions in the extent of my limited range, since almost all the processes that are discussed in this project take place all over the world and a massive number of people are involved. The analysis had to be narrowed to the processes that are mostly affected and the requirements as well as the solutions were focused on those.

The third objective was to investigate an ICT solution that could fulfill the requirements and at the same time could fit in the organization's current configurations.

8.2 RESULTS

Since the project is on conceptual basis and the resources for executing this study as well as the personnel's involvement were limited, the same apply for the results. These restrictions led the investigation towards a generic solution in some cases without the complete and in depth knowledge of the company.

The results of the first objective were presented extendedly in the third chapter, by describing the current problem situation. In addition, throughout the project, along with the company mentor that was appointed for this project, several meetings were held to raise awareness of the situation at the same time that we were looking for solutions.

With respect to the second objective of the project, the system analysis and the requirement identifications, the analysis was focused on the following use cases:

- Pre-install
- Install
- Preventive Maintenance
- Unscheduled downs – Diagnostics planning
- Complex upgrades
- Future machine & process redesign

By analyzing the situation for those major cases the research concluded to the following requirements:

<u>Functional requirements</u>

- Store data and documents that are already being produced by several working groups throughout the machine's lifecycle.
- Reinforce the current processes of obtaining the data.
- Create new processes to cover all the possible needed extracted data.
- Being able to retrieve the information produced from the customer's site for planning purposes, either via a GUI, or by another system.
- Analyze the information to deduct better prediction of functionalities for the future machines and machine versions.
- The reliability of the information should be maintained at a high level.

<u>IT requirements</u>

- High security of the data, files and information is essential, since they concern clients information.
- Ability to store data in form of parameters, layout drawings, raw data, and word files.
- The information system, even when the MACHINE X machines go to HVM phase, will have to handle low traffic volume of data, so the need for scalability will be moderate.
- The parameters in question will be very specific about each machine.
- The possibility for transforming the input data, parameters and files to meet the needs of the customers of the system.
- Communication compatibility with other systems such as PM planner.
- Limited simultaneous users of the system.

The final step and objective of the project was to investigate a possible ICT solution to cope with the problem that would also be able to integrate with the rest of the company's systems.

After 7 possible solutions where analyzed and compared to each other, the final solution proposed is the following: A Microsoft Access file, easy to create, that will store all the parameters and will be stored in the secure TCE server database, along with the rest of the files for each machine. The IT department will be responsible for the maintenance of the file and a CS FF engineer from each site will have to fill in the data and documents that SEED or pre-install engineers have collected in the customer field. The update of the information in the system will occur by request of the stakeholders.

8.3 RECOMMENDATIONS

The recommendations of the researcher for the company is to not focus on a stand-alone solution, but face the problem on a higher level, having a better overview. The problem should be integrated in a broader project that will improve the communications of information from inside the customers' Fabs to the company's operations and research facilities.

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APPENDIX

Key Characteristics	Importance for project	EXCEL SharePoint	ACCESS SharePoint	EXCEL TCE	ACCESS TCE	DMBS	IBM MAXIMO	SAP
Costs	**High**	**Very low**	**Very low**	**Very low**	**Very low**	**Average**	**High**	**High**
Cost of creation / purchase	High	Very low	Low	Very low	Low	Average	Very High	Very High
Cost of implementation	High	Very low	Very low	Very low	Very low	High	Low	Low
Costs of configuration	High	Very low	Very low	Very low	Very low	Low	Very High	Very High
Cost of maintenance	High	Low	Low	Low	Low	Average	Average	Average
Security	**Very High**	**High**	**High**	**High**	**Very high**	**High**	**High**	**High**
Security of data server	Very High	High	High	Very High	Very high	High	High	High
User account control	Very High	High	High	High	High	High	High	High
Capabilities	**Average**	**Low**	**Low**	**Low**	**Low**	**Average**	**High**	**High**
Availability	Low	Low	Average	Low	Average	High	Very High	Very High
Compatibility	Average	High	Low	High	Low	High	Average	Very High
Credibility	High	Low	Low	Low	Low	Average	High	High
Maturity	Average	Average	Low	Average	Low	Low	High	High
Extensibility	Low	Very Low	Low	Very Low	Low	Average	High	High
Flexibility	Average	High	High	High	High	Average	Low	Low
Scalability	Average	Very Low	Low	Very Low	Low	Average	High	High
Reliability	Low	High	High	High	High	High	High	High
Usability	**Average**	**High**	**High**	**Average**	**Average**	**High**	**High**	**High**
Learnability	Low	Very High	High	High	Average	High	Average	Average
Manageability	Average	Very High	High	Very High	High	High	Average	Average
Traceability	Average	Low	Low	Low	Low	Average	High	High
Understandability/Ease of use	High	Average	High	Low	Average	High	High	High
Maintainability	**High**	**Average**	**Average**	**Average**	**Average**	**Average**	**High**	
Durability	Low	Low	Average	Low	Average	Average	High	High
Efficiency	High	High	Average	High	Average	High	High	High
Robustness	Low	Low	Low	Low	Low	Average	High	High
Upgradeability	Average	High	High	High	High	Average	High	Average

Figure 20 Solutions full comparison