NATIONAL TECHNICAL UNIVERSITY OF ATHENS
SCHOOL OF RURAL & SURVEYING ENGINEERING
DEPARTMENT OF TOPOGRAPHY
AREA OF CADASTRE

The Volunteered Geographic Information in Land Administration: Crowdsourcing Techniques in Cadastral Surveys.

DOCTORAL DISSERTATION

for the title of Doctor of Philosophy in Engineering submitted in

the School of Rural & Surveying Engineering, National Technical University of Athens

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Diploma in Rural & Surveying Engineering N.T.U.A.

Master of Science in Geographic Information Science U.C.L.

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September 2015

ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ

ΣΧΟΛΗ ΑΓΡΟΝΟΜΩΝ ΚΑΙ ΤΟΠΟΓΡΑΦΩΝ ΜΗΧΑΝΙΚΩΝ

ΤΟΜΕΑΣ ΤΟΠΟΓΡΑΦΙΑΣ

ΓΝΩΣΤΙΚΗ ΠΕΡΙΟΧΗ ΚΤΗΜΑΤΟΛΟΓΙΟΥ

Η Εθελοντική Γεωγραφική Πληροφορία σε Συστήματα Διαχείρισης Γης. Τεχνικές που προέρχονται από τους πολίτες στη σύνταξη του Κτηματολογίου.

ΔΙΔΑΚΤΟΡΙΚΗ ΔΙΑΤΡΙΒΗ

για τον Επιστημονικό Τίτλο του Διδάκτορα Μηχανικού υποβληθείσα στη

Σχολή Αγρονόμων & Τοπογράφων Μηχανικών του Εθνικού Μετσόβιου Πολυτεχνείου

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Σεπτέμβριος 2015

The research was funded by a scholarship awarded by the Greek State Scholarships Foundation.

To my parents, Sotiris and Georgia

The only way to deal with an unfree world
is to become so absolutely free
that your very existence is an act of rebellion.

Albert Camus

Acknowledgments

I would like to express my sincere gratitude to the following people who have played an important part in my research:

My Supervisor, Associate Professor Chryssy Potsiou, for the trust she has shown in my research and the openness with which she embraced my ideas in an open and still unexplored academic field. I would also like to thank her for her tireless technical and scientific support within these five years of the research.

Professor Charalabos Ioannidis for his methodical supervision at academic and professional advice, his untiring guidance at all stages of the study, his valuable recommendations and his remarks in all publications, which supported this research technically and scientifically.

Assistant Professor Vassilios Vescoukis for his important scientific and technical suggestions and the innovative ideas he shared with me.

All other members of the examination committee: Associate Professor Cristina Capineri of Siena University for the opportunities offered to me within the terms of the IC 1203 COST Action "European Network Exploring Research into Geospatial Information Crowdsourcing: software and methodologies for harnessing geographic information from the crowd (ENERGIC)" and the great collaboration we have had, new ideas we have exchanged and perspectives we have explored together; Associate Professor Efi Dimopoulou for our five-year cooperation at the laboratory of Cadastre; and Professor Georg Gartner and Professor Hartmut Muller for their interest in my research, their support and for agreeing to examine this thesis.

Professor Muki Haklay, with special thanks for introducing me to Volunteered Geographic Information and giving me access to this new, open and extremely interesting academic field through his amazing and innovative ideas, his support and the opportunities that he has generously given to me since 2009, when we first met during my postgraduate studies at University College London.

Dr. Vyron Antoniou, Major in the Hellenic Army Geographic Directorate, Dr. Peter Mooney, Senior Research Fellow at the National University of Ireland Maynooth, and MA Robert Soden, PhD Student at the University of Colorado Boulder, who collaborated on the "Crowdsourced geographic information use in government" report to World Bank's Global Facility for Disaster Reduction and Recovery (GFDRR) under the supervision of Professor Muki Haklay. Kiru Pillay, Elizabeth McCartney, Cristina Capineri and Kate Chapman for their contribution to some of the case studies that are explored in this thesis. Findings of the report are presented in the third chapter and are used as a guideline for the proposed crowdsourced model for cadastral surveys.

The 250 anonymous volunteers who completed the questionnaire presented in the fifth chapter and all those who participated in the practical experiments presented in the sixth and seventh chapters of this doctoral dissertation. In particular, Irene Stamatelou, President of the community of Tsoukalades in Lefkada island, for providing support and help in the implementation of the first practical experiment in an agricultural area; the National Cadastre & Mapping Agency S.A. for providing the cadastral surveys for the Tsoukalades community; and all volunteers for their participation. Sofia Soile, MSc Surveyor Engineer at the Laboratory of Photogrammetry of N.T.U.A., with special thanks for her technical support in the cadastral mapping and manipulation of data derived from the volunteers in the Lefkada experiment; the undergraduate students of the School of Rural and Surveying Engineering who participated voluntarily in the two practical experiments carried out in Athens city center; and the residents at El. Venizelos district in Chania, Crete, for their participation in the last practical experiment.

The Greek State Scholarships Foundation, for funding my PhD studies and whose support is gratefully acknowledged.

My friends, who encouraged me in my thesis, believing in me and my dreams by showing great patience about my anxiety and absence due to the endless hours of work.

Finally, I would like to express my deepest love and appreciation to my family and especially to my parents, Sotiris and Georgia, who made me what I am, and offered me unconditional love, unwavering support and constant encouragement in all aspects of my personal journey. Their love will always cover me as a protective cloak and my deepest hope is to follow their path in professional and personal happiness.

Publications

This doctoral dissertation has been published in scientific journals and presented at international conferences after blind peer review in order to publicize and disseminate the research. In the list below, are given the most predominant publications.

1. Basiouka, S., Potsiou, C., 2015 A Proposed Crowdsourcing Cadastral Model: Taking Advantage of Previous Experience and Innovative Techniques. Book chapter in "European handbook of crowdsourced geographic information", IC 1203 COST ACTION, (under publication).

2. Basiouka, S., Potsiou, C., 2014 The OpenStreetMap For Cadastral Purposes: An Application Using VGI For Official Processes In Urban Areas. In: *Proceedings of the FIG Commission 3 Workshop on "Geospatial Crowdsourcing and VGI: Establishment of SDI & SIM*", Bologna, Italy. [The paper was awarded Best Workshop Paper by the FIG Commission 3 and it was published in *Survey Review* pp.1752270615Y-0000000011].

3. Haklay, M., Antoniou, V., Basiouka, S., Soden, R., and Mooney, P. 2014 Crowdsourced geographic information use in government, *Report to GFDRR* (World Bank). London, UK.

4. Basiouka, S., 2014 Citizen Mappers in Volunteered Cadastral Projects, In: *Proceedings of the 3ed Citizen CyberScience Summit*, London, United Kingdom.

5. Sylaiou, S., Basiouka, S., Patias, P., Stylianidis, S., 2013 The Volunteered Geographic Information in Archaeology *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume II-5/W1, pp.301-306. [The presentation has been awarded a prize in academic year 2013 from Thomaidio Bequest as a result of the competition entitled "Thomaidia Awards for the Progress of Science and Art"].

6. Basiouka, S., Potsiou, C., 2013 The Volunteered Geographic Information in Cadastre: perspectives and citizens' motivations over potential participation in mapping *GeoJournal,* vol. 79(**3**), pp. 343-355.

7. Sylaiou, S., Basiouka, S., Potsiou, C., Patias, P., 2012 Inspection of VGI applications in Cultural Heritage. *Horografies Journal*, vol. 3, ar. 1, pp. 15 – 22, ISSN 1792-3913 (in Greek).

8. Basiouka, S., Potsiou, C., 2012 VGI in Cadastre: a Greek experiment to investigate the potential of crowd sourcing techniques in Cadastral Mapping. *Survey Review*, vol. 44(**325**), pp. 153-161(9). [The paper has been awarded a prize in academic year 2012 from Thomaidio Bequest as a result of the competition entitled "Thomaidia Awards for the Progress of Science and Art"].

9. Basiouka, S., Potsiou, C., 2012 Improving cadastral survey procedures using crowd sourcing techniques. *Coordinates Magazine*, vol. VIII, issue 10, October 2012.

10. Potsiou, C., Basiouka, S., 2012 The Use of Volunteered Geospatial Information and crowd sourcing techniques to improve cadastral survey procedures, In: *Proceedings of the Annual World Bank Conference on Land and Poverty*, Washington D.C. U.S.A.

11. Basiouka, S., 2010 The use of dynamic maps and Volunteered Geographic Information in Greece. In: *Proceedings of the FIG Commission 3 Annual Meeting on "Information and Land Management. A Decade after the Millennium"*, Sofia, Bulgaria.

12. Kounadi, O., Basiouka, S., 2010 The phenomenon of Volunteered Geographic Information Science; The OpenstreetMap example in Athens and London. *Aeihoros Journal* vol 14, Special Issue, November 2010, pp 64 – 93 (in Greek).

13. Haklay, M., Basiouka, S., Antoniou, V., Ather, A., 2010 How many volunteers does it take to map an area well? The Validity of Linus' Law to Volunteered Geographic Information *The Cartographic Journal*, vol. 47(**4**), pp. 315-322(8).

Abstract

This research poses the principal question of whether the spatial and attribute data collected by volunteer landowners could be used in official Land Administration Systems (LAS) by mainly exploring the potential introduction of crowdsourcing techniques into official cadastral surveys as a simplified and transparent procedure undertaken with the aid of citizens.

This research aims to propose an alternative model based on Volunteered Geographic Information (VGI) that may be applied in various crowdsourced projects worldwide and explores its viability through theoretical investigation and practical experiments carried out by testing various methodologies and recruiting volunteers in various areas of interest. The Hellenic Cadastre (HC) project was selected as an interesting project of great national importance that may be used as a forerunner for this research. The research aims to introduce a new and open crowdsourced process, simplified and faster than previous models, where costs will be reduced and citizens will be actively involved.

This thesis presents the possibilities and perspectives of the potential use of crowdsourcing techniques for spatial and attribute data manipulation for interim cadastral maps and it is divided into two main stages: literature review and practical documentation. The study focuses on the use of new technologies, web-mapping tools, free-of-charge applications supported by smartphones, the first crowdsourced map, (OpenStreetMap (OSM)) and follows the sociological trend to be more citizen centered in decision making policies.

The literature review is given in chapters two to four and focuses on current trends, academic publications and practical applications of the use of crowdsourcing worldwide. The research defines theoretically the terms of VGI and LAS and builds on a proposed crowdsourced model for cadastral mapping. Various domains have been explored to approach the subject multilaterally. This research presents the era of the worldwide web before the advent of VGI, the evolution of web maps and the development of mashup maps as a forerunner of crowdsourcing techniques. The phenomenon of VGI is also explored in depth as a principal definition alongside other definitions adopted by the research community in order to analyze different aspects of the specific research field. Neogeography, crowdsourcing and citizen science are only a few terms illustrating different aspects of citizen involvement in data manipulation. Aspects of LAS related to various aspects of the cadastral procedure are also explored, including current definitions of this field.

Furthermore, the study explores various governmental examples worldwide, which have flourished with the aid of crowdsourcing techniques and citizen participation. It also analyzes the methodology, outcomes and perspectives around the potential of the crowdsourcing approach. By taking into account the above governmental case studies and the main lessons derived from them, the research sheds light on those components that are crucial for the success of a potential crowdsourcing cadastral project. Ten case

studies, which cover three main categories of disaster response, land management and public administration, are explored and analyzed in this thesis.

The literature review also focuses on the process, progress, legal framework and problems identified during recent years of the Hellenic Cadastre and ends by proposing a hybrid alternative crowdsourced model for cadastral surveys. The proposed model constitutes the main outcome of the literature review and is linked to the practical experiments that follow. The main innovative techniques, stakeholders and workflow derived from the proposed model are tested in the practical experiments.

The practical documentation consists of an investigation into citizens' opinions through a six-month survey and four practical experiments that were carried out in various areas of Greece. The practical part of the study is explored in chapters five to seven. First, the research made extended use of citizens' feedback by undertaking a study, which looked into their possible voluntary participation in cadastral mapping in Greece and the targeted motivations behind it. The volunteers' incentives for their participation in a governmental crowdsourcing project were integrated into the survey, which was completed by more than 250 citizens. The study recorded citizens' feedback regarding the official process, the necessity of the implementation of the Hellenic Cadastre and their general knowledge on technical aspects.

The nature of each practical experiment was different so that various approaches could be tested and elements important for further use could be isolated. The experiments covered different areas, volunteer groups, methodologies and mapping tools. The first experiment took place in the municipality of Kallithea, an urban area in south-east Athens. Nine young volunteers, undergraduate students and landowners participated by using a handheld Global Positioning System (GPS) and an iPad to trace seven blocks of buildings. The experiment was tested in two phases: the first phase collected tracks with a handheld GPS and proved that in urban areas this approach fails to meet official technical requirements. The second phase used an online service provided by the mapping agency and the volunteers digitized the boundaries of their land parcels on the orthophotos. This indicated that cadastral mapping can easily be undertaken using web-mapping tools in urban areas where accurate basemaps exist.

The second experiment was held in an extended area of Athens's historic city center and involved twenty volunteer undergraduate students who collected attribute and spatial data and updated the online dynamic map of OSM with the data. The students were asked to either collect GPS tracks or digitize the aerial imagery provided by the OSM and complete the attribute tables. Generalizations and rules were posed and the process was deemed promising for mapping in areas where accurate maps do not exist.

The third experiment took place in a rural area of Lefkada island, which has suffered long and multiple failures of the traditional procedures used for cadastral surveys. Fifteen volunteer landowners participated in a weekend experiment and collected geospatial data to delineate their land parcel boundaries on a cadastral map; the spatial data were collected using a handheld GPS and the editing of data was done afterwards at the laboratory. The volunteers' measurements were compared to the official measurements provided by the official mapping agency. The results were within 70% of the mapping agency's technical specifications.

The fourth experiment took place in the city of Chania on Crete, in a semi-urban area where ten volunteer landowners participated and traced land parcels using an iPhone. The experiment used free-of-charge mobile applications for attribute and spatial data collection and storage and showed the great potential of low cost equipment and easy-to-use software. The results of the experiment, when compared to the general urban plan of the area, showed that interim cadastral maps can be created using this method and the first phase of the official cadastral procedure can be easily simplified.

The first two case studies constitute experiments carried out in urban areas, while the last two constitute experiments carried out in rural and semi-rural areas. The different issues arising from these contexts necessitated different strategic plans.

The study ends by discussing the main findings of the research, presenting the general, technical and sociological outcomes and proposing further still unknown research fields.

Generally, this research follows the trend adopted during the last decade by governmental bodies towards open, inexpensive, quick and transparent processes involving citizens and applying new technologies to cadastral mapping. It is being gradually observed that the current trend for crowdsourcing will retain a fundamental role in the recent revolutionary use of spatial data. All the above experiments illustrate a great willingness of citizens towards participation and demonstrated new opportunities that could be adopted. They also highlight a slight differentiation between the altruistic reasons that were indicated as principal motivations in theory, and the oriented reasons that lead citizens to participate in practice, due to the nature and scope of the cadastral project. In conclusion, it should be noted that this research focused only on a small part of the VGI potential in land administration and it revealed a great potential for the adoption of new policies and especially VGI techniques in traditional procedures such as cadastral mapping.

Περίληψη

Η παρούσα διδακτορική διατριβή εστιάζει και διερευνά σε βάθος δύο εντελώς διαφορετικούς και ασύμβατους εκ πρώτης όψεως όρους. Την εθελοντική γεωγραφική πληροφορία, δηλαδή την χωρική πληροφορία που συλλέγεται και είναι επεξεργάσιμη από πολίτες καθώς και το ευρύ πεδίο της διαχείρισης γης που βρίσκει εφαρμογή σε μια πλειάδα ζητημάτων. Στην παρούσα έρευνα με τον όρο διαχείριση γης, τίθεται το ευρύτερο πλαίσιο εντός του οποίου τοποθετείται η δημιουργία κτηματολογικών βάσεων, η συλλογή γεωγραφικών δεδομένων για τη δημιουργία κτηματολογικών διαγραμμάτων και η σύνταξη του κτηματολογίου γενικότερα. Στο πρωταρχικό στάδιο της έρευνας τίθεται ο βασικός πυλώνας αυτής που βασίζεται σε ένα και μόνο ερώτημα. Μπορούν οι πολίτες να συμμετάσχουν ενεργά με συλλογή χωρικών και περιγραφικών δεδομένων στις κτηματογραφήσεις που γίνονται από τον επίσημο χαρτογραφικό φορέα, την ΕΚΧΑ Α.Ε.; Μπορούν γενικότερα τεχνικές που προέρχονται από το πλήθος να ενσωματωθούν στις επίσημες διαδικασίες σύνταξης του κτηματολογίου; Ο βασικότερος στόχος της έρευνας βασίζεται στην απλούστευση των διαδικασιών με παράλληλη μείωση του κόστους και του χρόνου που απαιτείται για την ολοκλήρωση της διαδικασίας και την ενεργή συμμετοχή των πολιτών ως ζωντανά κύτταρα της κοινωνίας. Παρ' ότι, η έρευνα εστιάζει στο ελληνικό παράδειγμα της κτηματογράφησης που αποτελεί ένα από τα βασικότερα ζητήματα διαχείρισης γης στον ελλαδικό χώρο, εντούτοις το προτεινόμενο μοντέλο που προκύπτει μέσα από την τεκμηρίωση της παρούσας εργασίας μπορεί ως γενικευμένο να χρησιμοποιηθεί σε εφαρμογές διαχείρισης γης παγκόσμια. Η παρούσα έρευνα βασίζεται τόσο σε θεωρητική τεκμηρίωση, με ανάλυση της βιβλιογραφίας και των παγκόσμιων εφαρμογών που έχουν αναπτυχθεί με την συνεισφορά της εθελοντικής γεωγραφικής πληροφορίας όσο και σε ευρήματα μέσα από μια σειρά πρακτικών πειραμάτων που εφαρμόστηκαν σε διαφορετικές περιοχές της χώρας, με διαφορετική φυσιογνωμία, διαφορετική μεθοδολογία αλλά πάντα με την συμμετοχή εθελοντών. Η παρούσα διδακτορική διατριβή εξετάζει τη βιωσιμότητα ενός μοντέλου ανοιχτού και συνδυάζει τεχνική τεκμηρίωση με κοινωνικές προεκτάσεις.

Στο θεωρητικό μέρος της έρευνας έγινε εκτενής βιβλιογραφική αναφορά των δημοσιεύσεων από την διεθνή ακαδημαϊκή κοινότητα επί του φαινομένου της εθελοντικής γεωγραφικής πληροφορίας και των αντίστοιχων ζητημάτων της διαχείρισης γης. Η έρευνα εστίασε στην εποχή του διαδικτύου πριν από τη συμμετοχή των πολιτών, στην ανάπτυξη τόσο των δυναμικών χαρτών όσο και των χαρτών που περικλείουν πληροφορία από διαφορετικές πηγές (mashup maps) ανάλογα με τα ενδιαφέροντα του «χαρτογράφου» που τον δημιουργεί και δόθηκαν αντίστοιχα παραδείγματα από τον ελληνικό και παγκόσμιο ιστό. Στη συνέχεια παρουσιάστηκε εκτενώς το φαινόμενο της εθελοντικής γεωγραφικής πληροφορίας και των συστημάτων διαχείρισης γης, αναδείχθηκαν οι αντίστοιχοι ορισμοί και δόθηκε έμφαση πολύπλευρα στις διαφορετικές πτυχές του αντικειμένου. Επιπλέον, δόθηκε έμφαση στον τρόπο σύνταξης του εθνικού κτηματολογίου, στις διαδικασίες που τηρούνται, την πρόοδο του έργου και τα προβλήματα που έχουν ανακύψει και καταγραφεί μέχρι σήμερα.

Επιπλέον, μελετήθηκαν 10 παγκόσμια παραδείγματα εθελοντικής γεωγραφικής πληροφορίας που αναπτύχθηκαν τα τελευταία χρόνια είτε ως εργαλεία αντιμετώπισης καταστροφών, είτε ως εργαλεία πρόληψης, είτε ως εργαλεία χωρικού σχεδιασμού και διαχείρισης γης με έμφαση

στη χωρική τους διάσταση, το ανθρώπινο δυναμικό, τα μέσα, το λογισμικό και την τεχνογνωσία που χρησιμοποιήθηκε. Πιο αναλυτικά, μελετήθηκαν η χαρτογράφηση της Αϊτής μετά τον καταστροφικό σεισμό του 2010, η χαρτογράφηση για την πρόληψη των φυσικών καταστροφών στην Ινδονησία καθώς και η εξειδίκευση αυτού του έργου με την προετοιμασία για πλημμυρικά συμβάντα στην Τζακάρτα, η χαρτογράφηση του νεοσύστατου κράτους του Νοτίου Σουδάν, η χαρτογράφηση της μεγαλύτερης παραγκούπολης στην Κένυα, η χαρτογράφηση υπηρεσιών για τους δημότες στην Νότια Αφρική, η χαρτογράφηση ανθρώπινων κατασκευών σε 50 πολιτείες της Αμερικής για τη δημιουργία εθνικού χάρτη, η χαρτογράφηση με χρήση δορυφορικών εικόνων στη Σομαλία, η ένταση δημοσιότητας των δράσεων δημοσίων φορέων, δήμων και τοπικών αυτοδιοικήσεων μέσω twitter στην Ιταλία και τέλος η χαρτογράφηση παραγκόσπιτων στην Ινδία. Βάσει της ανάλυσης των συγκεκριμένων παραδειγμάτων, επιλέχθηκαν εκείνα τα στοιχεία που θεωρούνται επιτυχημένα και χρήσιμα για την ανάπτυξη του υβριδικού μοντέλου συλλογής χωρικών δεδομένων από πολίτες και επεξεργασίας από τον επίσημο χαρτογραφικό φορέα που προτείνεται μέσα από την παρούσα διδακτορική διατριβή.

Τέλος, για την ολοκλήρωση της θεωρητικής προσέγγισης, διερευνήθηκαν τα κίνητρα των πολιτών σε μια 6μηνη έρευνα με ανώνυμα ερωτηματολόγια σε πλατφόρμα της google όπου συμμετείχαν 250 πολίτες. Η έρευνα χωρίστηκε σε τρία επίπεδα γενικών, ειδικών και προσωπικών ερωτήσεων όπου διερευνήθηκαν οι γνώσεις τους σε τεχνικό επίπεδο ενώ η ενότητα των ειδικών ερωτήσεων χωρίζεται σε τρία επίπεδα: στο πρώτο επίπεδο καταγράφηκε η τάση για τη χρήση των διαδικτυακών χαρτών, σε δεύτερο επίπεδο η εθελοντική γεωγραφική πληροφορία, η γνώμη των πολιτών για το εθνικό κτηματολόγιο και τέλος μια σειρά προσωπικών ερωτήσεων. Στην έρευνα συμμετείχαν συνολικά 145 γυναίκες και 105 άνδρες, εκ των οποίων το 16% είναι Μηχανικοί. Εν συντομία, η έρευνα απέδειξε ότι το 94% χρησιμοποιεί διαδικτυακούς διαδραστικούς χάρτες, το 51% θα συμμετείχε σε εθελοντική κτηματογράφηση, ενώ το 78% θεωρεί πως η ύπαρξη ενός αξιόπιστου συστήματος διαχείρισης γης προστατεύει την ιδιοκτησία σε ένα πλαίσιο δικαιότερης φορολόγησης και υποστήριξης της αγοράς ακινήτων και της γενικότερης ανάπτυξης.

Στο πρακτικό μέρος της έρευνας, 4 πειράματα σχεδιάστηκαν και εφαρμόστηκαν στον ελλαδικό χώρο, σε διαφορετικές περιοχές, με διαφορετικές μεθοδολογίες και διαφορετικά εργαλεία ως εναλλακτικές προτάσεις κτηματογράφησης με την συμμετοχή των πολιτών. Τα πειράματα χωρίζονται σε δύο βασικές κατηγορίες. Τα δύο πειράματα χρησιμοποιώντας διαφορετικές μεθοδολογίες, έλαβαν χώρα σε αστικές περιοχές του Νομού Αττικής. Το μεν πρώτο πείραμα έλαβε χώρα στο δήμο Καλλιθέας, με συμμετοχή φοιτητών της Σχολής Αγρονόμων και Τοπογράφων Μηχανικών ΕΜΠ (Σ.Α.Τ.Μ. Ε.Μ.Π.) και νεαρών κατοίκων της περιοχής. Συνολικά 9 εθελοντές συμμετείχαν, 7 μεγάλα οικοδομικά τετράγωνα χαρτογραφήθηκαν σε ένα πείραμα που διήρκησε μια μέρα. Αρχικά χρησιμοποιήθηκε ένα GPS χειρός, επειδή όμως κατά την επεξεργασία των χωρικών δεδομένων η ακρίβεια ήταν χαμηλή, το πείραμα επαναλήφθηκε με τη χρήση ενός tablet και των online εργαλείων χαρτογράφησης που παρέχει ο επίσημος χαρτογραφικός φορές (ΕΚΧΑ Α.Ε.). Το δεύτερο πείραμα σε αστική περιοχή, εκτελέστηκε με τη συμμετοχή 20 φοιτητών της Σ.Α.Τ.Μ Ε.Μ.Π. και τη χρήση του OpenStreetMap που αποτελεί τον πρώτο διαδικτυακό χάρτη με πληροφορία που προέρχεται από εθελοντές. Συνολικά, η περιοχή στο δυτικό τμήμα της Ακρόπολης, στην ιστορική συνοικία της Πλάκας χωρίστηκε σε δύο υποπεριοχές όπου χαρτογραφήθηκαν 95 οικοδομικά τετράγωνα με περιγραφική και χωρική πληροφορία χρησιμοποιώντας τα εργαλεία του OpenStreetMap.

Τα δύο επόμενα παραδείγματα εφαρμόστηκαν, το μεν πρώτο σε αγροτική περιοχή και το μεν δεύτερο σε ήμι-αγροτική. Το μεν πρώτο πείραμα έλαβε χώρα στο χωριό Τσουκαλάδες της Λευκάδας, σε μια περιοχή η οποία είναι υπό κτηματογράφηση τα τελευταία 12 χρόνια εξαιτίας αλλεπάλληλων αστοχιών που έχουν οδηγήσει σε μπλοκάρισμα των μεταβιβάσεων και της αξιοποίησης της περιοχής. Στο πείραμα συμμετείχαν 15 εθελοντές – κάτοικοι του χωριού όπου με τη βοήθεια ενός GPS χειρός υπέδειξαν και συνέλεξαν χωρικά δεδομένα για τα όρια 19 ιδιοκτησιών τους. Το πείραμα διήρκησε ένα σαββατοκύριακο ως προς τη συλλογή των χωρικών δεδομένων ενώ η επεξεργασία έγινε στο εργαστήριο. Το δεύτερο πείραμα έλαβε χώρα στην περιοχή της δημοτικής ενότητας Ελευθερίου Βενιζέλου του Δήμου Χανιων Κρήτης, όπου συλλέχθηκαν δεδομένα με τη χρήση ενός smartphone και χρήση ελεύθερων εφαρμογών για τη μέτρηση αποστάσεων, εμβαδών και εξαγωγή συντεταγμένων σε WGS 84. Στο πείραμα συμμετείχαν συνολικά 10 εθελοντές και συνέλεξαν χωρικά δεδομένα για 15 γεωτεμάχια σε χρονική διάρκεια 3 ημερών.

Η έρευνα συγκεντρώνει τα ευρήματα σε θεωρητικό και πρακτικό επίπεδο, παρουσιάζει ένα νέο φιλόδοξο μοντέλο, πιο ανοιχτό στην κοινωνία και τους πολίτες, στο πλαίσιο της συμμετοχικής δημοκρατίας, των νέων τεχνολογιών και των προοπτικών που διανοίγονται με επίκεντρο τους ιδιοκτήτες στη συλλογή των χωρικών και περιγραφικών δεδομένων έτσι ώστε το κόστος της σύνταξης των εθνικού κτηματολογίου να μειωθεί αισθητά και ο χρόνος ολοκλήρωσης του έργου ως μοχλός ανάπτυξης να ελαχιστοποιηθεί επίσης. Η έρευνα προτείνει πεδία για περαιτέρω ανάπτυξη με τη χρήση της εθελοντικής γεωγραφικής πληροφορίας σε ζητήματα διαχείρισης γης τόσο σε εθνικό όσο και σε παγκόσμιο επίπεδο και αποτελεί μια εναλλακτική πρόταση, η οποία έχει μελετηθεί τόσο θεωρητικά όσο και πρακτικά ώστε να αποδεικνύεται ως βιώσιμη.

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Abbreviations

AGI = *Ambient Geographic Information*

API = *Application Programming Interface*

CGI = *Contributed Geographic Information*

EETT = *Hellenic Telecommunications and Post Commission*

EL.STAT. = *Hellenic Statistical Authority*

FIG = *International Federation of Surveyors (Fédération Internationale des Géomètres)*

GIS = *Geographic Information Science*

GPS = *Global Positioning System*

GPX = *Global Positioning System Exchange Format*

GSDI = *Global Spatial Data Infrastructure*

HC = *Hellenic Cadastre*

HEMCO = *Hellenic Mapping and Cadastre Organization*

HEPOS = *Hellenic Positioning System*

HGRS 87 = *Hellenic Geodetic Reference System 1987*

IMF = *International Monetary Fund*

INSPIRE = *Infrastructure for Spatial Information in Europe*

iVGI = *Involuntary Geographic Information*

KML = *Keyhole Markup Language*

LADM = *Land Administration Domain Model*

LAS = *Land Administrative Systems*

LSO = *Long Scale Orthophotos*

NCMA S.A. = *National Cadastre & Mapping Agency S.A.*

NGO = *Non Governmental Organization*

NTUA = *National Technical University of Athens*

OSM = *OpenStreetMap*

SDI = *Spatial Data Infrastructure*

SRSE = *School of Rural and Survey Engineering*

UGC = *User Generated Content*

UNECE = *United Nations Economic Commission for Europe*

VGI = *Volunteered Geographic Information*

VLSO = *Very Long Scale Orthophotos*

WGS 84 = *World Geodetic System 1984*

WPLA = *UN-ECE Working Party for Land Administration'*

WWW = *World Wide Web*

1. INTRODUCTION

1.1. Introduction

This dissertation thesis consists of eight chapters and the main study is presented in chapters two to eight. The first chapter summarizes the research objectives, motivations, methodology and the outline of the study, which are considered in five sub-chapters. The following pages first illustrate the scope and aims, hypothesis and adopted methodology of the research. Moreover, the main innovations of the research are given in separate keynotes. The introductory chapter ends by giving the outline of the study as it is structured in the following chapters.

➢ Objectives of the research.
➢ Motivations of the research.
➢ Innovations of the research.
➢ Methodological framework of the research.
➢ Outline of the structure of the thesis.

Table 1-1: Predominant components of the first chapter

1.2. Objectives of the research

The study investigates two different academic fields; Volunteered Geographic Information (VGI) and Land Administration Systems (LAS) and explores the potential of integrating the techniques of crowdsourcing into official cadastral mapping. The scope of the study is to propose a well-defined model that could be simplified in a general form and could be applied in various Land Administration case studies worldwide as a forerunner to wider applications. The research starts by posing the fundamental questions to be explored: Is it possible for the techniques of crowdsourcing to be introduced into official cadastral surveys and in LAS more widely? Are citizens able to actively take part in decision making policies? How can the process of cadastral mapping be enhanced, simplified and open to volunteers, and also flexible enough in terms of software usage and data manipulation? What are the effects of such a cadastral mapping project and what are its expected benefits? The interest of the research community over the developing phenomenon of crowdsourcing is growing. Not just the variety of definitions that have been developed within the last nine years, but also the variety of projects worldwide that adopt crowdsourcing techniques, reveal how this new practice has infiltrated governmental projects, voluntary actions and emergency circumstances.

The study demonstrates the critical theoretical and practical components of crowdsourcing, which lead to an alternative proposal joining the two fields, VGI and LAS, and presents its conclusions in chapter eight. The research primarily focuses on the sociological and technical aspects that derive from combining techniques of crowdsourcing in cadastral mapping and is not restrained by issues of legislation and privacy. Experience has indicated that the legal framework can be easily modified when required reforms are blocked due to the legal restrictions. It should be noted that concerns over privacy and personal data could be encountered at national or international levels by the institutions involved in crowdsourcing. Initially, this research aims to deal with the unknown, hence attractive, world of VGI in general, to investigate it technically and sociologically and to propose a general model that could be applied worldwide.

This research is divided into two parts: a) the literature review of the VGI phenomenon and its various applications worldwide, the identification of volunteers' motivations and the possibility of VGI integration in Greek mapping practice and, b) the practical documentation including experiments, data analysis and quality control of the results.

As part of the literature review, in chapters two to five, a thorough examination of the development of crowdsourcing, VGI and LAS is presented. A review emphasizing the developments in web mapping, the definitions and the various terms that have emerged in recent years in crowdsourcing and the field of land administration is given in chapter two. Chapter three investigates successful worldwide case studies using crowdsourcing in map updating and chapter four initiates a proposed model for cadastral surveys according to the main lessons that have been derived from the previous case studies. The proposed model is based on the successful use of human resources, and it firmly supports the participation of volunteers in spatial and attribute cadastral data collection. In each area, team leaders train and support landowners and other citizens in technical matters. All participants act voluntarily. The proposed model encourages the participation of young volunteers such as undergraduate students of technical schools, as well as other, similarly motivated local people.

In terms of technical documentation, chapter five further investigates a six-month research project in the form of a questionnaire given to 250 volunteers and which documented citizens' feedback about the official mapping procedure and their motivations for becoming involved in a potential participatory cadastral mapping exercise. This survey also illustrated the sociological aspects of the research. The result was a clarification of the general incentives and the targeted motivations for voluntary participation in governmental projects, which enhanced the background theory of the proposed model. Chapters six and seven explore various approaches in data collection and management by taking into account the nature of the area of interest and the targeted needs. Some of the approaches tested include collecting GPS tracks, digitizing orthophotos provided by the official mapping agency and using OpenStreetMap (OSM) in the creation of interim cadastral maps to identify the boundaries of land parcels in countries where no accurate basemaps are available. Given the required differences in their management, urban and rural areas were approached differently. Urban areas were handled by using web-mapping tools, online dynamic maps and the voluntary contributions of citizens from a distance. Rural areas required more field work due to two main factors: the difficulty of identifying the boundaries on orthophotos and restrictions in accuracy, which, however, were dealt with by using land measurements. In practice, volunteers (landowners and undergraduate students of the School of Rural and Surveying Engineering) were recruited to participate in practical experiments and to collect attribute and spatial data about their private properties, while adopting different methodologies and tools. The volunteers stored private attribute data using mobile applications and they also evaluated the entire process of every experiment. Given that the official process, according to Greek legislation, is based on a core scientific number of stages where surveyors, lawyers and IT technicians are the ones to collect, edit, store and handle data, the proposed idea has proven somewhat innovative. To date, citizens are excluded at all stages, except from the declaration of their private property at the beginning of the process. The cadastral mapping experiments were designed and applied for the first time worldwide; hence the results were unknown. The experiments were concluded after an evaluation of the outcomes by the research team at the laboratory afterwards.

As part of the experimental research to combine VGI and cadastral surveys, the Hellenic Cadastre project (HC) was selected as a challenging LAS case study. The HC project started in 1995 and has attracted worldwide attention, as well as Greek government and European Union interest, for different and sometimes controversial reasons, namely taxation, development and protection of private properties. In this context, the HC project was selected because of its national impact and its global reputation: a complex project with many rights and holders to be recorded, it is designed for a developed property market, which suffers great delays and financial waste. The context and experience gained offers the opportunity to focus on this project as a forerunner for others. In sociological terms, it is also remarkable that the HC project has been implemented while Greece has been suffering from a financial recession, which has affected social solidarity and trust in the government and its policies over the last six years.

The aim of this study is summarized as follows:

- Simplification and transparency of official procedures.
- Reduction of compilation time for cadastral surveys, in comparison to official procedures.
- Reduction of costs.
- Involvement of citizens as active cells of the society in an effort to reduce errors and increase accuracy.

Due to the nature of the project and this research into it, which covers a variety of aspects including technical, economic and sociological, the findings could be easily simplified and adopted by other governmental crowdsourcing projects worldwide.

Although the principal question posed at the beginning of the research summarizes the interest in introducing crowdsourcing techniques into cadastral surveys, the main objectives also include efforts to:

- Launch a new alternative crowdsourced model for cadastral surveys worldwide which may also be applied in Greek cadastral surveys. The model is supported by volunteers and uses new technical innovations and methodologies that take advantage of the possibilities and existing understandings of governmental crowdsourcing projects. The study aspires to take advantage of citizen participation for the implementation of the project. The study tests the possibility of introducing crowdsourcing techniques into official cadastral surveys.

- Identify the successful lessons derived from other crowdsourced mapping projects that have taken place worldwide during the recent years. Extensive research investigated various crowdsourced mapping examples worldwide and isolated their main lessons.

- Estimate the motivations and incentives behind a potential governmental project such as cadastral surveys. Through the design and distribution of an anonymous survey, the research records and evaluates technical and sociological issues in depth, theoretically and practically.

- Test experiments in terms of the accuracy of the outcomes and investigate various approaches and crowdsourcing techniques based on the requirements of each area of interest. Four different applications constitute the core part of the practical research of this study. Although, they present great differences, they all have a common basis in that they all adopt crowdsourcing techniques. The main objective here is to prove that firmly defined professional procedures are not the only efficient ones.

- Present interesting outcomes, analyze its findings, make recommendations for further research and put forward specific proposals to the academic society.

The hypothesis of the research is positively oriented towards the implementation of the above targets and it is divided into two main stages. The first investigates whether VGI techniques can be incorporated into official cadastral procedures more specifically. The second is focused on the design and presentation of a general crowdsourced model for cadastral surveys, which can be used in various administrative applications worldwide.

1.3. Motivations of the research

Various ideas and motivations led to the decision to undertake technical research combined with a sociological perspective in order to innovative techniques and ambiguous methodologies:

- The HC project started in 1995 and although it is considered as of principal importance by the state and citizens, it is still incomplete. It is vital to design a flexible and open model with citizens' participation to speed up the process.

- The research is carried out within a period during which Greek society has been significantly affected by the financial recession and has lost its trust in the state and government. The specific study hopes to offer an alternative solution to an existing land administration problem in Greece and give a boost to the property market and economic development. Its main purpose is not only to offer its services to the government and support good decision making, fair taxation and economic development but also to support citizens and release their properties and the capital invested in them as a vital part of overcoming the economic crisis. The main objectives that have motivated the initiation of this research are focused on the removal of citizens from the margins of decision making policies that affect their lives. The research also aims to begin an international trend and present its outcomes as services to societies, citizens and governments to speed up the establishment of more general LAS worldwide.

- A strong motivation has also been derived from the nature of the research, which combines various aspects that affect not only the technical and professional community but also has a wider implementation and interest in sociological perspectives. Targeted research with only a technical focus may remain limited in applicability for various reasons. A wider study open to the public and evaluated by governments, official mapping agencies, local authorities and citizens may offer various benefits with short- and long-term applications that are still unexplored by researchers. The challenge of this study is, among others, to combine different academic fields and propose a model that will affect all citizens directly.

- Finally, the study aims to face the challenge of solving the specific problem, to propose an alternative, viable model for cadastral surveys and the adjudication of landowners, and open a brand new and still unexplored field of research about the implementation of cadastral surveys in a humanitarian framework with technical documentation.

1.4. Innovations of the research

The main innovations that the specific research presents cover an extensive field of technical, theoretical, practical and sociological aspects and are listed below:

- Although crowdsourcing has been used for mapping purposes, in this study crowdsourcing techniques are linked to cadastral procedures for the first time. Within a well-defined model of volunteers, citizens, technicians, surveyors and experts, a new and more flexible open procedure is proposed.

- The innovative approach is focused on introducing crowdsourcing and the involvement of volunteers to cadastral surveys, in order to eliminate the gross errors of the formal procedure as local volunteers know the area better and may help in the adjudication process.

- The research synthesizes various keynotes from international crowdsourced mapping projects with formal procedures, and designs an alternative crowdsourced model for cadastral surveys according to the main lessons learnt. A flexible and general crowdsourced model for cadastral surveys that can be applied in land administration projects is designed and tested for its functionality and is enhanced according to the practical findings.

- The study includes innovative research into the specific motivations of local volunteers to participate in a cadastral mapping project for the benefit of the national economy and the prosperity of all.

1.5. Methodological framework of the research

The research is divided into three main stages: proposal, doing and analyzing, writing and presenting [Figure 1.1] and follows the pattern introduced by ACS (2008) in its presentation "Doing research". The first stage is focused on the definition of the problem, the initiation of its main targets and scope, and the plan of the next stage, which includes the practical part of the research investigation.

The second stage is constituted of the analysis of the research and includes the execution and control of the four practical experiments that were carried out. Within this stage, the quantitative controls are also included. The last stage is focused on writing and presenting the whole work of this study and it closes the specific research cycle.

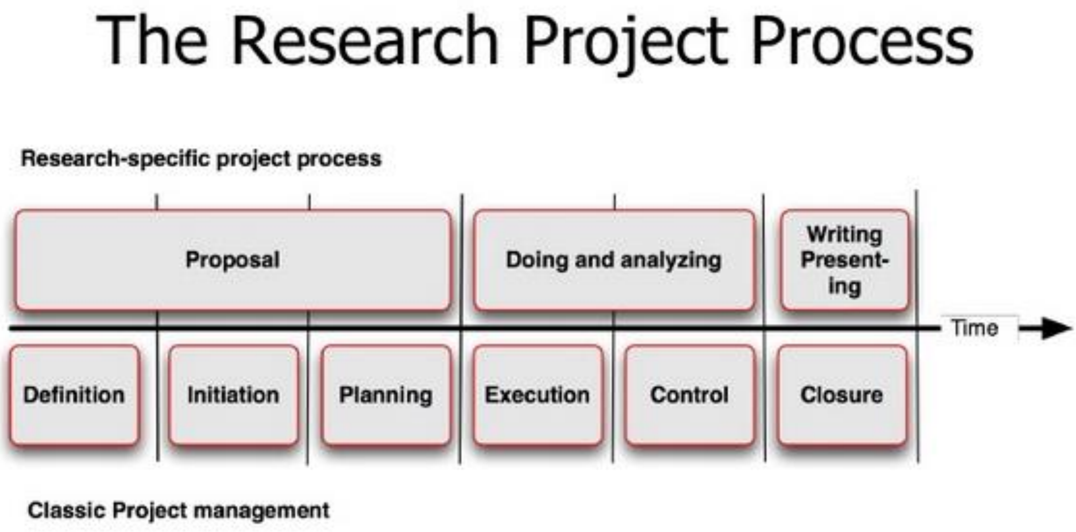


Figure 1-1: The research project process (source: ACS, 2008)

In a more general framework, according to Kothari (2004) the specific research is:

a) ***Descriptive*** and includes surveys and findings based on practical experiments. The main characteristic of this kind of research is that the researcher has no control of the variables and applies comparative and correlational methods to discover causes. Another term given for this kind of research is ex-post facto research.
b) ***Applied*** as it aims at finding a solution for an existing problem that society faces and takes advantage of action instead of pure theoretical research. Applied research is targeted in social, economic or political contexts that affect a large part of the population and where the need for a solution is pressing.
c) ***Empirical***, although this has come accidentally through an abstract idea and primarily presents characteristics of the conceptual research. It is "data-based research, coming up with conclusions which are capable of being verified by observation or experiment".

According to the same perspective, the specific research approach is both experimental and simulative. It is an ***experimental approach*** as it adopted practical experiments to observe their effect on other variables and recruited volunteers to investigate the principal idea. It is also a ***simulation approach*** as it involved the construction of an artificial environment within which relevant information and data can be generated.

The practical part of the research, which is constituted by the four case studies, follows the philosophy of replication as first noted by Yin (1993). The practical experiments investigate the simulation of real circumstances in cadastral surveys and not a simplistic logic. For each separate occasion two different experiments were carried out following Yin's observation, which supports the implementation of several case studies to amplify confidence in the overall results. The main idea behind the investigation of the case studies is not new. As Yin (1989) also noted a few years earlier, "it is an empirical inquiry that investigates a contemporary phenomenon within its real life context using multiple sources of evidence". Anderson (1993) sheds light on another aspect by underlining that case studies help to clarify how and why things happen, allowing the investigation of contextual realities and the differences between what was planned and what actually occurred. Thorough research across the specific field has been carried out by Baharein Mohd Noor (2008) who underlined that "Case studies become particularly useful where one needs to understand some particular problem or situation in great depth, and where one can identify cases rich in information" and their three main advantages are that: they enable the researcher to gain an holistic view of a certain phenomenon; they can be useful in capturing the emergent and immanent properties of life in organizations; and they can also allow generalizations. The benefits of the specific approach are obvious. The case studies can shed light to an innovative field that is greatly unexplored with unknown potential and also offers the required generalizations in the experiments such that they can be adopted on future occasions.

1.6. Outline of the structure of the study

The study consists of eight chapters based on the theoretical approach and the technical experiments, which have been investigated in two areas: rural and urban. The first four chapters are focused on the theoretical components of the study and the last four on the practical experiments and their outcomes, as well as the conclusions and further proposals.

The ***first chapter*** is the introduction, which gives the structure of the study and its main chapters. This chapter identifies the scope and the aims of the research, its objectives and its hypothesis. It also highlights the motivations and illustrates its main innovative points. The chapter concludes by presenting the methodological framework that was adopted for the research.

The ***second chapter*** presents the literature review of the research from the identification of Geographic Information Systems in 1992 until the emergence of the term "Volunteered Geographic Information" in 2007, its parameters, strengths and concerns in accordance with the frame of its development. All different terms that have been given to the phenomenon of non-expert participation in spatial data manipulation are introduced. The principal different terms of VGI, crowdsourcing and citizen science, and all other secondary terms which shed light to different aspects of the phenomenon behind the same philosophy are mentioned. Basic aspects of LAS and its principal components are given. The review starts from the era before the advent of VGI, dynamic and mashup maps and their wide application on the Web and continues with the new era by displaying the merging of two different academic fields: crowdsourcing and LAS. The chapter concludes by presenting the main highlights of the previous research that has been carried out about VGI accuracy.

The ***third chapter*** is focused on the crowdsourcing methodology as applied to successful examples worldwide. Within the frame of this research, various case studies that flourished with the aid of volunteers and crowdsourcing techniques are explored in their technical and sociological aspects. The case studies constitute a wide range of applications, which were launched due to different incentives in various areas of mapping interest. Ten case studies are presented in total and are analyzed in depth as a guide for future crowdsourcing projects. Those ingredients that are evaluated as important for the success of other potential mapping projects are isolated and recorded.

The ***fourth chapter*** starts by presenting the current situation of the HC project, its progress and the main deficiencies that it faces. The research focuses on its official process and implementation time required, its legal framework and the gross errors that have been recorded in areas that are under cadastral survey. As a consequence of the official process, the potential crowdsourced model for cadastral surveys was designed and proposed for implementation as an alternative methodology for official cadastral procedures. The workflow, stakeholders of the experiment, adopted successful lessons and coordination of the proposed model with the Infrastructure for Spatial Information in Europe (INSPIRE) directive are the main examined aspects here.

The ***fifth chapter*** explores volunteers' motivations in a six-month survey where more than 250 citizens completed an anonymous questionnaire about the potential of their voluntary participation in cadastral mapping. The survey was divided into three main categories collecting general, technical and targeted information. The sample of potential volunteers was divided into two main categories: those who are willing to participate and those who are not. Generally, the results were positive in terms of citizens' willingness to participate. Greece is in a difficult economic situation, which primarily has social effects, and therefore the fundamental motivations are focused on the general improvement of cadastral procedures by speeding them up. Participants recognized the need for a nationwide LAS as a tool to facilitate the property market and enhance economic growth.

The practical part of the research, explored in the sixth and seventh chapters, is constituted by four individual experiments, which present slight differentiations in adopted methodology, equipment and participants. The main goal of all the experiments is focused on the potential to incorporate crowdsourcing techniques into official cadastral procedures. The four experiments are divided into two main categories: the first two experiments were carried out in urban areas and the other two were carried out in rural or semi-rural areas. This decision was based on the different accuracy requirements that each area needs. In three of the experiments, landowners participated voluntarily after having been trained by a team leader. In one experiment, undergraduate students were recruited for participation in the research. In the former three case studies, the data editing was done in the laboratory by the research team. In the latter experiment, the whole process was successfully implemented by the students. Different equipment was used for the data collection: handheld GPS, online tools that are provided by the official mapping agency, free-of-charge Apps in smartphones and online crowdsourced maps such as OSM. The core part of the research remained the same. Volunteers collected spatial cadastral data after having been trained by experts for the creation of interim cadastral maps.

The ***sixth chapter*** is focused on the practical applications carried out in urban areas. The first experiment took place at the municipality of Kallithea, an urban area close to the center of Athens. The owners have made declarations of ownership but the process has not passed to the second phase. Nine volunteers participated and seven land parcels were traced using one handheld GPS and one iPad. The results using the handheld GPS were moderate compared to the technical specifications required by the official mapping agency. Due to signal obstacles, the accuracy was not satisfactory so the experiment was concluded with online digitization of the land parcels on the online application provided by the official mapping agency. The second experiment was carried out in the center of Athens and it aimed to explore the potential of using the first crowdsourced map, named OpenStreetMap (OSM), for cadastral procedures in urban areas as an alternative proposition. The research team carried out a practical experiment with the aid of twenty undergraduate students of the School of Rural and Surveying Engineering who were asked to collect attribute and cadastral spatial data in an extended part of the historic center of Athens and update the OSM, an online dynamic map, with attribute and cadastral data. The experiment was focused on the OSM methodology, which constitutes a significant part of the VGI philosophy.

The ***seventh chapter*** is focused on the two practical experiments that took place in rural and semi-rural areas of interest, on two Greek islands. The first practical experiment took place on the island of Lefkada, at the rural village Tsoukalades, which has suffered long and multiple failures of the traditional procedures used for cadastral surveys. The last experiment took place at the city of Chania on Crete, in a semi-rural area where the cadastral process has been concluded but the city plans have been under implementation for the last 30 years. Ten volunteers participated and fifteen land parcels were traced by using an iPhone for spatial data collection and attribute data storage. Free mobile applications were used during the last experiment. The volunteers not only collected spatial data of the boundaries of their land parcels but they also captured photos and geotagged their location, stored personal data and showed great familiarity with smartphones and mobile applications despite their level of education. The research in all experiments indicated that citizens are not only capable of participating in cadastral mapping but also that their involvement is crucial for the project's success.

The ***last chapter*** summarizes the findings, highlights and conclusions, and provides further proposals derived from the five-year study carried out within the terms of this research. The chapter is divided into three main parts: the first part is focused on the discussion of the research, the second adopts the successful lessons learnt and the last gives an overview of the future fields of this research and investigation.

The outline of the research is given in Figure 1.2.

Figure 1-2: The structure of the research

2. LITERATURE REVIEW

2.1. Introduction

The World Wide Web (WWW) has led to an increase in the electronic distribution of maps and two main factors have led to a revolution in Geographic Information Science (GIS) and spatial data. The first factor is based on web mapping and online dynamic maps, which users navigate in a modern way when they seek geospatial information, as Cartwright (2003) revealed. The second factor is based on participation in the data collection and map editing which has given citizens an active role. It is obvious that the participation of volunteers in mapping constitutes the physical evolution of dynamic maps.

On the one hand, new terms such as Neogeography (Turner 2006, Sui 2007), ubiquitous cartography (Gartner *et al*, 2007) and web mapping (Plewe 2007) have been introduced so that the phenomenon can be identified and GIS has come to be characterized as volunteered (Goodchild, 2007). The phenomenon has been enhanced with new terms such as citizen science, which proves how dynamic it is.

On the other hand, land management and proper LAS constitute a set of processes where spatial information has a fundamental role. Land Administration is defined as the process of determining, recording and disseminating information about the tenure, value and use of land when implementing land management policies (UNECE, 1996). The transition from land information to land resources, which defines land management, can only be successful if spatial data is held properly. As UN (2005) mentions, an increased demand for electronic access to land-related data has led to greater empower of citizens. It is only recently that Potsiou (2015) underlined the great impact that surveyors can have in this new era, and its challenges. Potsiou (2015) also admits that surveyors should be prepared to deal with data editing, to cope with the large amount of information that is collected in a relatively short time with the participation of many volunteers, and they should also maintain in-depth technical research, better education and cooperation with other experts.

The main target that is posed within this research is to demonstrate theoretically and practically that crowdsourcing techniques can be incorporated within the official procedures in a LAS that could be applied with minor differentiations worldwide.

The second chapter investigates international publications, introduces the basic terms of the crowdsourcing phenomenon and explores the field of LAS in an effort to combine these two different academic fields under the Hellenic Cadastre project design and its implementation. The research first explores the web era before the VGI evolution, dynamic maps, mashup maps and a few successful Greek examples; and the different terms that have been coined by the research community so that crowdsourced mapping can be analyzed and described. It also investigates the need for a proper LAS and its strong correlation to the HC as a basic tool for land development.

The table 2.1 indicates the main components of the second chapter.

➢ The chapter investigates the state of the field as a first step of the research. The study first aims to identify the era before the advent of VGI, how maps have evolved with the evolution of dynamic and mashup maps and what the spatial revolution really includes. As Greece is chosen to be the area of application and testing of the proposed model for cadastral surveys, the context in Greece is also highlighted and representative examples of local and national maps are given.
➢ Voluntary participation in mapping is also explored, including VGI, crowdsourcing techniques, extreme citizen science and various other similar terms.
➢ The first crowdsourced map, OSM, and its application in Greece, is investigated separately as a principal part of the crowdsourcing philosophy.
➢ The study also analyzes the other academic field under consideration, LAS, including spatial data infrastructures and the Cadastre.
➢ Previous research carried out by the research community on the accuracy of crowdsourced mapping data is explored in depth.
➢ The chapter ends by asking the fundamental question of whether crowdsourcing techniques can be incorporated within land administrative applications and sheds light on the accuracy of VGI.

Table 2-1: Predominant components of the second chapter

2.2. The web era before the advent of VGI

Three main terms are combined in the exploration of web-era mapping before the advent of VGI: the World Wide Web (WWW), online mapping and GIS.

GIS is designed for storing, managing, analyzing and presenting spatial information. As reported by Longley *et al.* (2005) "almost everything that happens, happens somewhere. Knowing where something happens is critically important" and "with a single collection of tools, GIS is able to turn from a curiosity-driven science to a practical problem-solving". Goodchild (1992) first introduced the term Geographic Information Science for issues raised around the technology that collects and manages spatial data in a technological manner. The WWW has led to a revolution in spatial data representation, cartography and mapping and has offered an increase in the electronic distribution of maps.

According to Peterson (1997), the Internet is not only becoming the major way of map distribution but this revolution also has great impact on GIS and the methods that have been adopted in digital mapping. Doyle *et al.* (1998) supports the same observation by noting that the advent of computers facilitates the advance of GIS, multimedia and virtual reality. He also underlines the effect of electronic power on the introduction of GIS in daily life. According to Pulter (2009), the transition from static to dynamic GIS maps is essential especially when it is taken into account that real world geographic objects are changing through time. It was however Peterson (1997) who first recognized the success of dynamic maps where users' actions are responded to in real time by a map server. The first dynamic map was Xerox Parc Map Viewer, built from static maps. From 1996, conventional GIS packages started to launch their own platforms and applications (Haklay, 2008). The use of online maps was restricted for many years to basic tools and applications designed by companies to include technical knowledge and which were addressed to a very specific user community.

The general fact that “accessing maps via the web has become perhaps the first step for the general public when they seek geospatial information” (Cartwright, 2003) has been enhanced during recent years due to the active participation of non-experts not only in data use but also in data manipulation. Perkins & Dodge (2008) describe the main reasons for the exploitation of geospatial information. Not only affordable computer power but also the mass markets for GPS and broadband Internet have led in this direction. Keogh & Fraser (2006) also present free satellite imagery as one of the most important tools in map data displays. The research community is also moving in this direction and adds new definitions to the correlation of spatial analysis and the web. The term “geospatial web” was first introduced by Scharl (2007). He refers to geospatial interfaces as “simple yet powerful navigational aids that facilitate the real-time access and manipulation of geospatially and semantically referenced information.” A similar term, “geoweb” appears in the literature in Hub *et al.* (2008), however Elwood (2010), uses the term geoweb as an abbreviation for the geospatial web.

As a consequence, a new era has developed on the web, which has caused a great evolution in digital mapping. Between static and dynamic maps, which constitute different forms of mapping, the most successful are interactive maps where a map server responds to users’ actions in real time, as Peterson (1997) admits. The involvement of amateurs in data manipulation, which makes the role of users and creators indistinguishable, has offered a new perspective on the distribution of dynamic maps.

2.2.1. Mashup maps

The new era in spatial data dissemination has without doubt arisen following the introduction of dynamic maps on web. Mashup maps are a special category of dynamic maps. The term “mashup” was first introduced in music where bits of different songs were combined to make a new song (Hastings, 2007). Wong (2008) states that the definition of mashup is somewhat dynamic and mashup maps are an entire category of mashups. In fact mashup maps constitute a category of dynamic maps, which provide special interest because they can aggregate spatial information from different sources. However, Wong disagrees by characterizing mashups as challenging and inspiring applications reflecting users’ interests and how these can be combined in innovative ways. Kulathuramaiyer (2007) divides mashups into categories; mapping mashups, timeline mashups, photo-organization mashups, meta-search mashups, custom interface mashups, and content structuring mashups. The separation is not absolute and there are many applications that overlay two or more subcategories.

The Programmeableweb (Programmeableweb, 2010) [Figure 2.1.] website groups all mashup applications by dividing them into categories depending on their purpose. According to the Programmableweb there are more than 6,199 mashups worldwide, three times more than the number charted by the same site in 2007. However, the number is quite moderate. Mashups are currently estimated at more than 1 million unique applications. Based on the latest statistics mashup mapping constitutes 37% of all mashups, the highest percentage compared to all other categories.

Why are mashup maps so special and such an essential part of web mapping? Not only do mashups combine separate stand-alone applications in an innovative project, which creates countless maps, but the source code can also be used without modification. This means most applications can function through an API without any changes to the original code. Educause Learning Initiative (2007) underlines that Google or Yahoo maps are used as basemaps in most cases. However mashup maps will not function if these services are interrupted or discontinued. There are a variety of mashup maps depending on creators' taste and interest. There is also a differentiation between the maps that can be enhanced by the user, such as Wikimapia, or can only be used without their content being modified by the user.

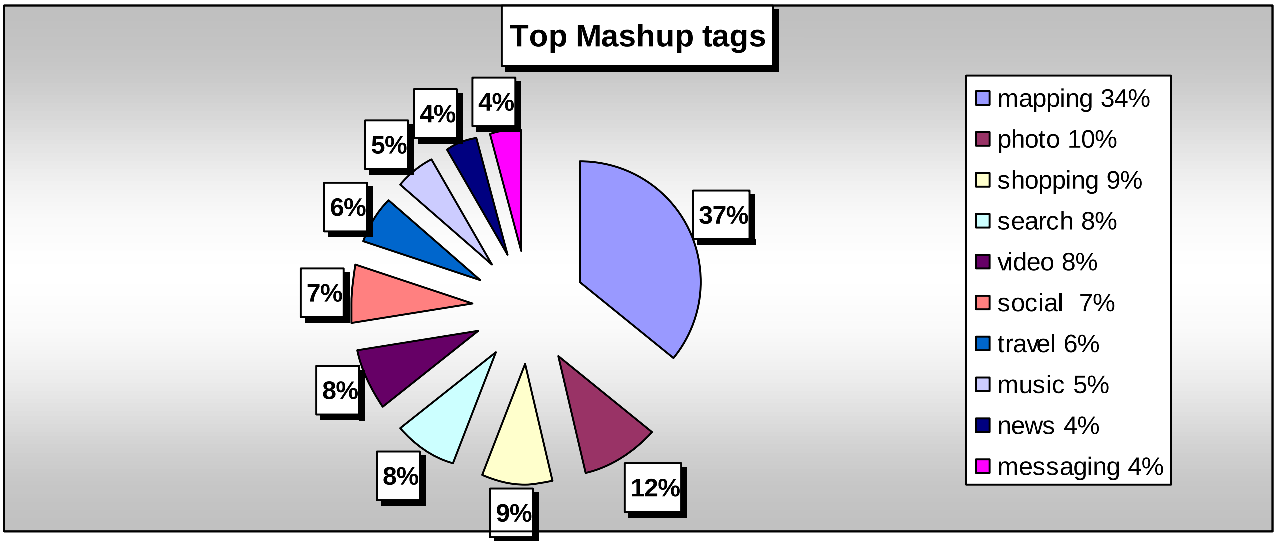


Figure 2-1: Top mashup tags (source: Programmeable website, 2010)

2.2.2. Dynamic maps in Greece

This research aims to have a worldwide impact within the terms of its proposed crowdsourced model for cadastral surveys and its tests but it takes advantage of the Hellenic experience as a forerunner for discussions and important outcomes.

The most common use of web maps in Greece is based on dynamic maps with users adding, removing, changing layers to receive the desired result. Online dynamic maps are provided for a variety of applications, from road navigation in the city center of Athens to locating points of interest such as pharmacies or petrol stations in the suburbs. Users' participation is limited in this category as they can obtain information and develop the desired map but they cannot contribute to data selection or editing, which is the core part of user generated content (UGC).

This specific trend has spread in Greece as the use of electronic computers and broadband Internet has increased. According to the last study by the Hellenic Telecommunications and Post Commission (EETT), Internet penetration in Greece had reached 46% in November 2014. There are a total of 3,026,631 broadband connections, more than the 2,105,076 connections recorded in early 2010, which approaches 27.4%

broadband penetration. The percentage accelerates year by year; however recording of this by the official authorities is quite slow. Currently, Greece is in 17th position among the EU member states in terms of broadband penetration.

Dynamic maps and the subcategory of mashup maps have been spread through a variety of Greek websites concerning a plurality of subjects. However, according to this research, there are five dominant categories that have attracted users' interest in Greece: education, public administration, environment, leisure and improvement in daily life. The categories are not clearly separated and can overlap in different fields. However, their main division is given below:

- Education

Dynamic maps have been incorporated in the educational system where students are taught geography by using dynamic atlases. Students learn how to navigate, collect information, compose thematic maps and create content by using educational software (Geografia, 2010).

- Public Administration

The public sector and administration have only recently introduced dynamic maps in their services so that they offer a spatial dimension. The most representative example is the Hellenic Statistical Authority (EL.STAT.), which has launched a dynamic map with information about the temporary, de facto, permanent and legal population of every municipality and prefecture. The information is also supplemented with other attribute information that may be interesting to citizens. The service is offered at a charge (Hellenic Statistical Authority, 2015).

- Environment

WWF Hellas (WWF Hellas, 2010) has created a dynamic map integrating all the information concerning environment, climate change, hydrology and topography. Users can see the Natura protected areas, national woodlands, land use and Ramsar wetland areas among other relevant spatial information. Users are free to add or remove layers so that they produce the desired map but they cannot contribute in any other way.

- Entertainment

Websites that combine social networking with mashup maps where users are free to upload their photos or mention their presence in specific areas are quite popular in Greece. The best known are Flickr (Flickr, 2015) and Foursquare (Foursquare, 2015) where spatial correlation is required. As Ortiz de Urbina (2010) has underlined this new trend introduces geography to entertainment and social connection offering the opportunity to all consumers to tag their favourite places.

The Municipality of Athens (Athens Maps, 2010) website, for example, offers the opportunity for citizens to use Google maps to find a variety of points of interest from schools to cash machines in the wider region. There is also a similar but informal initiative provided by a blog (Athensville, 2010) where citizens can find the best tasting ice cream in the city, the area where Chinese street food is served or other information. Little-known spots and small secrets of Athens are revealed on a Google map.

- Improvement of daily life

The National Technical University of Athens (NTUA) has created a multimodal dynamic map of greater Athens which is based on simulated conditions and shows the traffic in the city center in real time (Athens Traffic Map, 2010). It estimates the average time to move between points chosen by the user and answers the question of how far you can go in 15 minutes. The service also supports mobile notification.

All the above maps offer an interaction between the server and the user, so the content changes according to the commands that the user gives and the produced result varies depending on the restrictions that the cartographer has posed.

2.3. The new era on the web: terms and definitions for voluntary participation.

The great revolution that has taken place in GIS has led to dramatic change in the source, use and manipulation of spatial information during the last decade. Sui (2008) and others name it as "digital spatial data which is collected and edited not by data producers but by citizens who are not experts but are willing to disseminate their spatial knowledge and observations" without any special invitation (Seeger, 2008).

Blaut *et al.* (2003) had earlier noted the specific predisposition of all human beings to map by underlining that all people have natural mapping abilities. According to Kingsley (2007), civil society shares the same goals and has created a non-hierarchical network of self-organized individuals who participate in it. In fact he predicted the evolution of mapping, the involvement of amateurs with the aid of web tools and the alteration of role distribution between mapping agencies and users (Budhathoki *et al.*, 2008). According to his research, large organizations are unique GI producers and their products are firstly promoted to expert organizations and secondly to individual users. The revolution occurs through VGI, which results in a new era of GI relationships. GI production is distributed to all quarters and it is clear that GI products can be produced and shared by everyone. In terms of participation, the use, manipulation and editing of geographical information has been fundamentally democratized (Haklay, 2013). Ortiz de Urbina (2010) has also underlined this statement.

Terms like *Neogeography* (Turner 2006), *Volunteered Geographic Information* (Goodchild 2007), *web mapping* (Plewe 2007) and *ubiquitous cartography* (Gartner *et al.* 2007) were used to present the new trend in GIS. Elwood (2008) states that there are different definitions that distinguish online spatial information into two main categories. First category includes *web mapping* and *ubiquitous cartography*, which emphasize not only the mapping itself, but also the practices that could be adopted in order to make online interactive mapping more attractive to new users. The second category, of *user-generated content* and *VGI* determine the focus on how spatial data is derived, i.e. the source and processes through which they are collected and used. All these terms are parts of *Neogeography* (Turner, 2006), which constitutes a general category including all of the above. It is clear that although various terms are used, the general meaning is the same and is based on a crowdsourcing philosophy.

The impact that this trend has had on cartography is underlined by Gartner *et al.* (2007) who states that “Maps and map-making have become ubiquitous, and this phenomenon requires cartographers to rethink basic concepts about map design and map use”. The trend seems to be stable if not increasing and Buchroithner & Gartner (2013) introduced the term “Neocartography” to show how Neogeography has penetrated a very traditional research field such as Cartography.

The word Neogeography is derived from the combination of the two Greek words for new and geography, and depicts the new trend recently introduced in GIS. According to Satyaprakash (2008), Neogeography was developed when the traditional form of GIS was mature enough. Although, Neogeography is understood as a term developed in this specific research field in 2006, it was first coined in a comment included in the “Yearbook” of the Institution of Washington in 1922, which mentioned that “Palaeogeography has a far wider field and can only be defined in the terms of Neogeography”. The next reference is found in the “Encyclopaedia of Bible Life” in 1944. Between 1950 and 1954, the “Chronica Botanica: an international biological and agricultural series” refers to the term in a different academic field. The term Neogeography is also reported in a sociological publication in 1952 by an anonymous source. The French philosopher Francois Dagognet in 1977 titles his book as “Epistemology of the Concrete Space: NeoGeography”. Finally, the term is referenced by Baker in a chapter of his book titled “Reclaiming San Francisco: History, Politics, Culture” in 1998 (d-log, 2008).

“Where historically a professional cartographer might use conventional packages of GIS, compare Mercator versus Mollweide projections, and resolve land disputes, a new geographer uses a mapping API like Google Maps, talks about GPX versus KML and geotags his photos to make a map of his summer vacations.” This explanation, by Turner (2006), reflects the general ideas behind ***Neogeography***. In other words, Neogeography allows users to use and manage geographic information and tools according to their interests without taking into account specific cartographic rules and mapping techniques. The users are as versatile as the medium itself allows them to be and as inventive as the maps they produce. As Turner (2006) has underlined “Neogeography means “new geography” and consists of a set of techniques and tools that fall outside the realm of traditional GIS, Geographic Information Systems”. The term was similarly introduced by Sczott (2006) in his blog, where he underlined that “although specific patterns have been posed by the scientific community, Neogeography is based on the personal, intuitive, artistic and temperamental users’ applications”. As Wyngaardem & Waters (2007) summarize, the traditional format of spatial information presented in the appropriate scale, projection and format has been transformed in maps that contain content which is derived from different sources in an effort to create maps and visualizations. According to Roche (2010), Neogeography is only a neologism that introduces the era of geospatial democratization including new technologies, standards, practices and user-creators.

Crowdsourcing refers to a more general phenomenon of data that derives from the crowd or in other words is related to the wisdom of the crowd, as Surowiecki (2004) states in the “Wisdom of the Crowds: Why the Many are Smarter than the Few”. The term was coined by Sieber (2007) in the way that it is currently used and is considered to be a similar term to UGC, which was first coined by Howe (2006) in his article "the rise of crowdsourcing". Neither crowdsourcing nor UGC are new terms; Cook (2008) conducted historical research into the term with a focus on the origin of spatial data. Both terms are focused on spatial data and its origins and they may be applied in a variety of academic fields, applications and contents, however in the case of spatial information that is collected by users (UGC) (Sieber 2007) or spatial information derived from the crowd (crowdsourcing), the information and its origin must be controlled and evaluated. The first effort to relate crowdsourcing to land management was done in the publication of "Rapid Urbanization and MegaCities: the need for Spatial Information Management" (Doytcher *et al.*, 2010) where another similar term is given for crowdsourcing. Within the concept of crowdsourcing, citizens volunteer to collect and often manipulate data in a variety of applications for good governance, which may include urban management.

A similar term has been given by MacGillavry (2003) who uses ***collaborative mapping***, which is "an initiative to collectively create models of real-world locations online, that people can then access and use to virtually annotate locations in space."

The term ***citizen science*** entered the English Oxford dictionary only recently in June 2014 and is directly linked to participatory research and more specifically to participatory mapping where "non-professional scientists voluntarily participate in data manipulation for scientific projects", as Cohn (2008) and Silvertown (2009) first referred to it. The term was first introduced by Rick Bonney of Cornell's Laboratory of Ornithology in 1995. According to Haklay (2013) citizen science applies to a wider academic field and its boundaries may not be clearly geographic. Haklay (2013) in the same publication also supports a hierarchical typology in terms of citizen participation ranging from level 1, which refers to crowdsourcing, to level 3, which is extreme citizen science and involves collaboration between citizens and scientists in problem definition, collection and data analysis. ***Extreme citizen science***, which is a reformed and more specialized term introduced by Haklay (2013), includes problem definition, data collection and analysis by the volunteers so that a "completely integrated activity is required".

It is Sieber (2007) who underlines that ***user generated content*** (UGC) is produced by users of the web and promotes the rise of social networking. The equality of opportunity to publish is one important factor of its success. More recently, Krumm *et al.* (2008) have referred to "pervasive UGC", where UGC moves from the desktop into people's lives, e.g. through mobile devices, community building, raising awareness, etc.

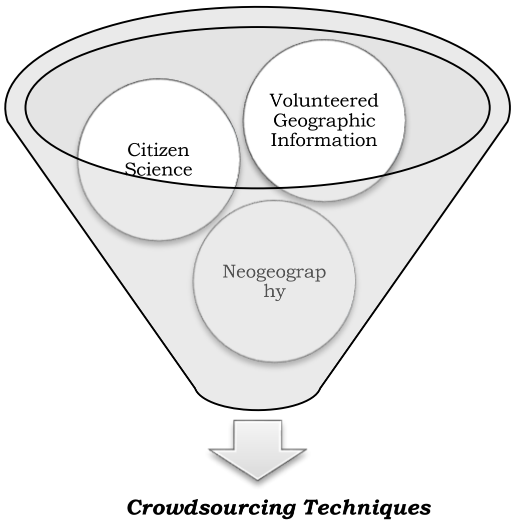


Figure 2-2: Different definitions that support crowdsourcing techniques

Although, all the above definitions are similar and support the same phenomenon and philosophy in a general framework, VGI focuses on its geographical perspective, as its name suggests. Due to its specific benefit, ***Volunteered Geographic Information*** (VGI) is one of the most widely deployed and disseminated terms. In its publication entitled "Citizens as sensors: The World of Volunteered Geography" Goodchild (2007) uses the term VGI for the first time, indicating that the participation of a large number of people, often with few qualifications, is now widespread. The term was readily adopted by the research community worldwide to explain the phenomenon and was widespread in different fields of application. Declaring the great innovation represented by the great engagement of citizens in GIS creation, Goodchild (2008) first noted the change to the relationship between the public and spatial data. Amateurs collect spatial information in a scientific area that for a long time was monopolized by official cartographic organizations. It is about an individual effort by amateurs who act voluntarily in GIS data collection, editing and management, and their results may or may not be accurate, according to his research. The main goal of the new field is the participation of citizens: everyone can be involved by collecting and uploading data or by editing entries and monitoring the results – in spatial data management, in other words. Elwood (2008) was the first who distinguished the fact that the term VGI is focused on the data itself, its use and its origins. Budhathoki *et al.* (2008) correlated the relationships between mapping agencies and users in the past and present to indicate how the forms have changed. Haklay (2012) underlines that VGI supports the production of geographical information so that the official mapping agencies can update their data and Antoniou *et al.* (2010) have extensively studied the accuracy issues that have puzzled the academic community. VGI is adopted as a principal term in the whole research arena for two main reasons. Not only does it include the geographical dimension, as Haklay (2012) underlined, but it is also the most used definition in terms of accuracy and use in official mapping projects. It is clear that no matter which term is used by the research community, all have the implementation of crowdsourcing techniques in common [Figure 2.2].

Supplementary terms have been recently introduced by various scientists worldwide in order to support the great innovation occurring within the phenomenon and the resonance of the voluntary trend. ***Ambient Geographic Information*** (AGI) first appeared in Stefanidis *et al.* (2013) in relation to the analysis of Twitter data. Stefanidis *et al.* refers to the messages that have geographic footprints such as tweets that constitute ambient geographic information as they capture references of locations that are simply momentary social hotspots. ***Contributed Geographic Information*** (CGI) was given as a term by Harvey (2013) and ***Involuntary Geographic Information*** (iVGI) was introduced by Fischer (2012). All terms investigate GI and find innovative adjectives to shed light on different aspects of the phenomenon, which can be simply understood as voluntary manipulation of spatial data by citizens.

2.3.1. Why Volunteered Geographic Information?

The principal reasons that play a critical role in the adoption of VGI may be divided into three main categories: technical, economic and social reasons. Mobile penetration, low cost of data collection and management, reduction in time, the great number of participants and the transformation of citizens into active roles in aspects of spatial data collection and use are only a few sub-categories of the three main categories, which may overlap and are not always clearly separated.

- Technical reasons

Mobile phones have a central role in data collection by volunteers and their penetration has played a critical role in the creation of a spatially enabled society. Two thirds (2/3) of the global population do not have access to the Internet. On the contrary, 87% has a mobile phone. The percentage of the population in developing countries with a mobile phone has risen to 79%. Moreover, mobile GIS is a powerful tool that can provide the necessary updated and reliable digital spatial data, under crucial circumstances. In this way, the obstacles (lack of funding, infrastructure, personnel, etc.) that existed for the creation of, and access to, necessary digital spatial information are eliminated. Thus many more citizens can enjoy m-series and are enabled to improve their living standards and all their life activities moving into a new world, the mWorld (mobile world), as it is called by the experts.

Widespread broadband connection and dissemination of dynamic maps (Perkins & Dodge, 2008), easy-to-use equipment and handheld GPS are a few other technical factors that have contributed to VGI projects. Currently, the expansion of GPS equipment, broadband Internet and reduced computer costs also assist towards progress in this direction.

- Economic reasons

Affordable computer power, low-cost equipment, time saving and limited cost of procedures are the four fundamental economic reasons that make crowdsourcing techniques flourish. It is well accepted that national mapping agencies need more time and money for mapmaking than the communities that offer their services voluntarily. Moreover, as Mayo (2007) admits, there are many voluntary organizations that complain about being unable to afford official mapping data. Also, Perkins & Dodge (2008) state that the cost of national mapping agencies is extremely high. According to Goodchild (2008) the reason for this is that a topographic map costs approximately US$100,000 to be produced, without calculating the compiling and printing investments. Rhind (1996) also refers to the dramatic changes that have influenced most national mapping organizations. As a consequence, they are not willing to offer their products free of charge, especially due to the high cost of map production.

- Social reasons

Human reasons are also included among the various technological and economic aspects. First of all, the incentives of participants vary a great deal. Many researchers have tried to figure them out. Goodchild (2007) presents two fundamental reasons. The first one is based on the self-promotion an individual hope to gain from participation in the project. It is remarkable that after the creation of Mapchester the majority of people asked for feedback as to how much they had done. The second reason may derive from personal satisfaction. Everyone feels satisfied by contributing to the completeness of such an ambitious effort. Tulloch (2008) considers that achieving a higher level of empowerment may also be a considerable reason for participating in VGI projects. All these crowdsourcing activities can be characterized as attractive from the aspect of participation as well as connection. However, the most important reason may be the benefits that will be gained from the completion of a VGI project.

Secondly, VGI has cultivated a sense of locality. It is recognized that no one knows a local area better than its residents. In many cases, the whole crowdsourcing project is based on the aid provided by local people. Mapchester was created within a weekend and was a project carried out in Manchester city where local volunteers were asked to map their city and enhance it with points of interest. The whole effort was based on residents' aid. Seeger (2008) noted that a volunteer offers valid information only if he/she is local or part of the community. The most remarkable example is the information provided to the whole world by residents after Hurricane Katrina and the Haiti earthquake. Goodchild (2008) summarizes the need of local contribution to mapmaking in one phrase by saying that "residents of a neighborhood are inherently experts in the local area".

However, a few concerns arise due to the volunteers' involvement in local activities. Elwood (2008) writes that differentiations in the assigned geographic information may be noticed due to citizens' priorities, experiences and identities. Among the main concerns that are posed, the most predominant are what Tulloch (2008) names "digital vandalism", "yelling" and "deliberate misdirection". The impacts on VGI projects are crucial, and they may be various and lower the quality of the data. Although Flanagin (2008) notes the importance of credibility as a combination of trust and expertise, trustworthiness and expertise have both objective and subjective components. It is clear that VGI is based on subjective reasons.

2.3.2. The first crowdsourced map: OpenStreetMap (OSM)

Kingsley (2007) first introduced the term of "civil society" for a non-hierarchical network of self-organized individuals who contribute to mapping by using global mechanisms. The most representative example of online mapping based on volunteers' participation is OSM, which is a global, online, up-to-date, dynamic map derived from civil society. OSM was launched by Steve Coast in 2004 in the United Kingdom and was spread to many countries in a relatively short time. The *Guardian* newspaper included OSM in its top five of a list of 100 mapping-related websites in 2009. As the welcome message says on the home page of OSM: "The OSM is a free, editable map of the whole world. It is made by people like you".

The main innovation that makes it unique is that it has been created by non-experts. Its main purpose is the creation of a free digital map of the whole world, which will be created by non-experts. The main factors of its success fall in to four categories: time, cost, public participation and free distribution of data. The speed through which the project has been covered has been extremely rapid. Volunteers have mapped large areas in a relatively short time. It is undeniable that the national mapping agencies would need more time and money to map such areas. The cost is also an important factor, which has seen OSM become so successful. Not only is the equipment more affordable but the staff also offers its services voluntarily. Moreover, OSM is a nonprofit social network, which means that the users are not bombarded with advertisements or other commercial offers. OSM follows Brown's (2001) philosophy that the web would be better off if the community was left to non-profit entities. The users of OSM are not exploited in other ways for the services offered to them. Figure 2.3 shows the procedure for creating OSM: data are collected by handheld GPS or smartphones and uploaded onto the server where data is edited and rendered.

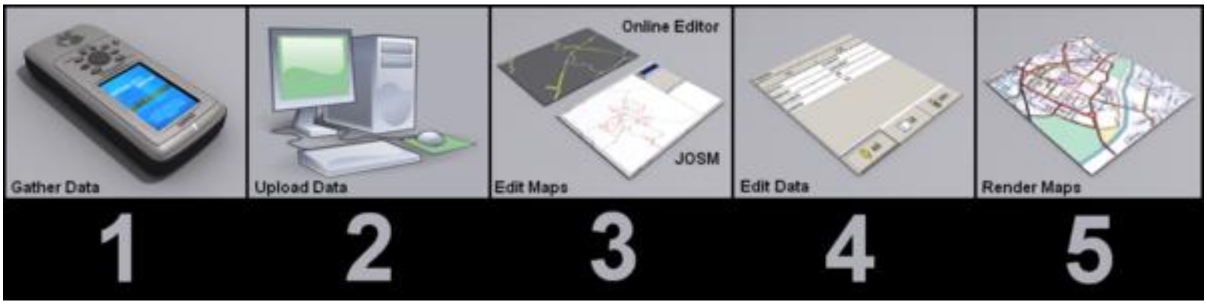


Figure 2-3: The five steps of creating an OSM (source: OpenStreetMap, Beginners' Guide, 2009)

2.3.3. OSM in Greece

Research carried out in 2010 by the author (Basiouka, 2010) indicated that OSM in Greece is at a moderate level compared to other European countries. For example, compared to the Netherlands, where volunteered mapping has been totally completed (consisting of 0.25% of the world), Greece has a lot of progress to make. Among the 61 most populous Greek towns, 31% of them are totally unmapped in OSM, while 62% of them are moderately mapped. Only the four main cities are really well mapped and can be compared to conventional datasets. Taking into account the population of each city in relation to the level of mapping, there is a strict correlation as the graph reveals in Figure 2.4.

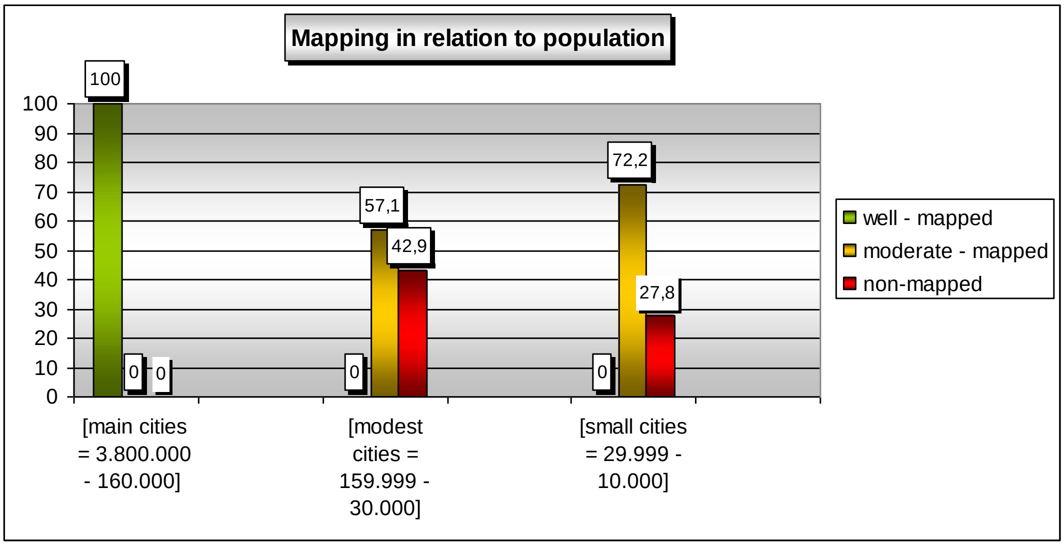


Figure 2-4: Level of mapping in relation to the population of Greece (source: Sofia Basiouka, 2010)

Another element that contributes to the speed of the mapping is how close a city is located to the sea. This research proves that maritime cities are better mapped than non-maritime ones due to touristic, financial and commercial interests. The percentage of non-mapped maritime cities in Greece in OSM is 20%, while for non-maritime cities it exceeds 40% [Figure 2.5.].

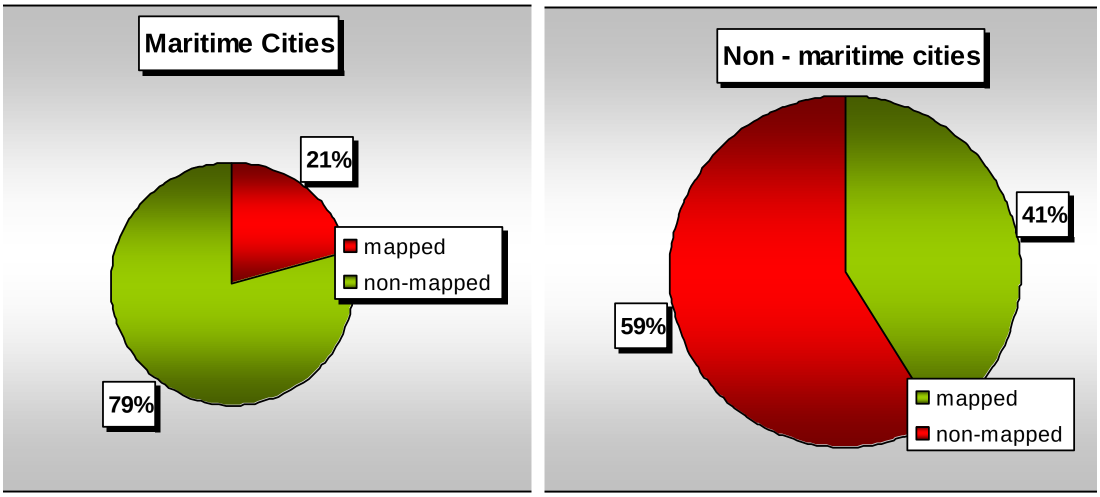


Figure 2-5: Mapping in relation to closeness to the sea (source: Sofia Basiouka, 2010)

Volunteers in Greece have adopted the example of other countries and created their own forum on the OSM website. They contribute to OSM mapping by collecting tracks with GPS, copying Yahoo imagery or editing maps created for the 2004 Olympic Games, which are not restricted by copyright. A representative example is in the city of Volos. No teams have been created yet for OSM mapping so everyone collects and edits tracks individually. However, they exchange their opinions and share ideas. Their main concerns are focused on naming and categorizing the different points of interest, or which technique is considered more accurate for data collection between GPS and Yahoo maps.

It is clear that the OSM project has attracted volunteers' interest and its utility will increase as its quality is improved, and its content will be extended to unmapped areas. The Ministry for the Environment, Energy and Climate Change has developed a portal (Geodata Maps, 2010) where citizens can download spatial data free of charge and OSM is used as a base map verifying its oncoming value.

2.3.4. Other VGI applications

Taking into account that each dataset should be "fit for purpose" and meet specific requirements and user expectations (Coote & Rachman 2008), various applications have been launched during the last five years based on crowdsourcing techniques. A key fact is that volunteers' motivations vary and depend on the nature and importance of the applications. Thus, there are three main areas of spatial information use based on voluntary participation by citizens. A survey (Coleman *et al.* 2010) has classified citizen participation in three main categories: the first one meets the need of citizens with free spatial data unlike commercial services, such as commercial navigation maps; the second one is based on social networks and contains information of interest to those who collect it; and the third is based on governmental initiatives. Navigation, leisure and crisis management are the principal areas that have been developed with the aid of VGI based on various citizens' requirements (Sylaiou *et al.* 2012).

Non-commercial Maps: The initiative for creating and developing non-commercial maps is focused on VGI. The most basic are ones intended for navigation and general mapping. The use of the VGI tool started as a movement unlike the commercial navigation agencies, in order to reduce the cost of acquiring and upgrading data. The most representative example is OSM, which was analyzed previously.

Social Network Mapping: These are the maps resulting from increased Internet use in combination with social networks. As Ethier (2003) reported, the theory behind social network mapping is based on the study of these networks and the mapping of their relationships, which can be applied to a wide range of groups, from small communities to entire nations. Characteristic examples of such maps are those that use Flickr and are generally based on the practice of mashup mapping, or those that use the Ushahidi platform to crowdsource information using multiple channels, including SMS, email, Twitter and the web.

Leisure has evolved due to the expansion of smartphones, which offered easy and quick access to all social media from every part of the planet and which are connected to the Internet. According to Gartner (2012), 472 million smartphones were sold, corresponding to 31 % of mobile communication device sales. Among the most popular applications on social media are Foursquare and Flickr, which were the first spatial applications to launch spatial checks on users' placement and photograph sharing, respectively. Facebook and Instagram, in an effort to expand into the geospatial market, also introduced checks on places and photographs. It is not irrelevant that Instagram's spatial tagging is powered by Foursquare and the whole application was bought by Facebook for 1 billion dollars in a deal that was finalized in April 2012 (Inc, 2012). Entertainment and social engagement are among the obvious motivations to engage volunteers in these applications.

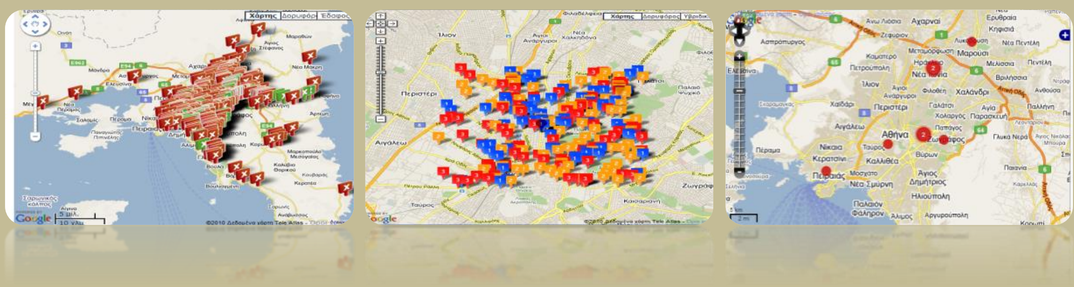
Disaster Response Mapping: The maps that arise as society needs to address small or large problems of a local or global scale (e.g. crisis management) may even involve the entire planet and are developed with the help of awareness among citizens. Crisis management is a field that was rapidly affected by VGI. The 2010 Haiti earthquake (Humanitarian OpenStreetMap Team, Haiti, 2010) is a representative example of a sudden event which motivated volunteers to participate in order to save lives and support official aid in a clear, altruistic and humanitarian framework. The Libyan crisis (iRevolution, 2011c) and the earthquake and tsunami in Japan (Ushahidi, 2011) were also mapped with social media support and VGI software.

The first maps based on UGC launched in Greece are focused on issues of the daily life, and have been introduced by official agencies that strictly support and require citizens' participation to get improved content. Although, the trend is widely spread worldwide, it is still in its infant stages in Greece. Figure 2.6 shows the most recent applications.

An application based on UGC is the website referring to illegal signs in public areas and on the facades of buildings. The aim of the initiative supported by the state and the Ministry of Transportation is focused on the removal of illegal advertising signs, which are responsible for distracting drivers and causing accidents. The application requires citizens' participation and spatial familiarity with maps (Illegal signs, 2010). The backdrop is based on Google maps and the volunteers are free to tag their point of interest and upload a photo on the map. Eight hundred and seventy-five verified accusations have been declared and 175 have been removed to date. The participation of volunteers is at its highest levels in the capital of Athens and the second biggest city of Greece, Thessaloniki.

The second application is Pin Project (The Pin Project, 2010), which has a similar philosophy to the illegal sign effort and is supported by the Road Safety Institute (P.M.). The aim of the application is to mark potholes spatially on a map. Volunteers can tag the point of interest, rate its importance and add additional descriptive information. It is based on voluntary citizen tagging. Google maps are used as a backdrop and the project is limited to the city of Athens at the moment.

Mapping public areas where people with disabilities have restricted access is the aim of the AmeA hotspotting application (ΑμεΑ hotspotting, 2010). Users can report the point of interest spatially, upload a photo and add supplementary comments. The effort of recording problematic spots offers users an active role as members of society.



"Illegal signs" — *http://www.illegalsigns.gov.gr*

"The pin project" — *http://www.msfree.gr/pin/*

"ΑμεΑ hotspotting" — *http://www.amea.eu*

Figure 2-6: Popular dynamic maps in Greece

The last example may not support the rules that a UGC map provides to its users, but it is a great tool that has been designed by the official mapping agency and facilitates surveyors' work. It is also a representative example of the capacities that online maps can provide to their users. An online application has been developed by the official mapping agency (NCMA S.A.), named "Orthophotos – viewing service" and composed of orthophotos taken between 2007 and 2009, except for borderlands and areas protected by the Greek military (NCMA S.A. Viewing Service, 2015). The orthophotos provide spatial analysis at a scale of 20cm in urban areas and 50cm in rural areas. The online map supports the majority of tools provided by typical GI systems and online maps while covering a series of functionalities. The user can digitize polygons and extract the desired shape with its coordinates, measurements and distances with great accuracy. Users can also import DXF files and coordinates, and search by map location, road name or identify points of interest (POIs). Its main advantage is based on the capability of the user to create a cadastral extract in a desired scale accompanied by the coordinates in HGRS 87. Due to the accuracy in urban areas, the application also offers great potential in cadastral mapping such that field surveys could be eliminated and only reference points would need to be measured for control. This application was available from the beginning of this research so it was used in the design of the experiments. The online application was adopted as an alternative methodology in one of the four experiments carried out in

Athens. Figure 2.7 presents the cadastral extract (left) and the interface of the application (right).

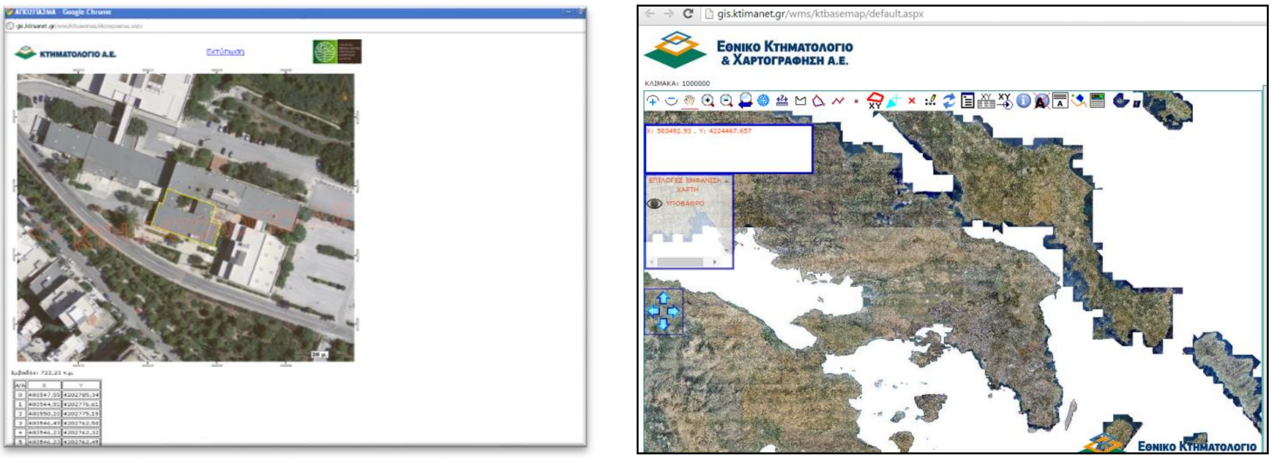


Figure 2-7: The School of Rural and Surveying Engineering at the NTUA as it is shown on the online application (source: NCMA S.A.)

2.4. Land Administration and cadastral mapping

Within the new web-based era and the great possibilities offered to users via dynamic maps and new technologies to manipulate data, another field presents great interest due to its socio-economic perspectives. ***Land Administration*** is a relatively new term, which was introduced in the 1990s. Theoretically, Land Administration is defined as the process of determining, recording and disseminating information about the tenure, value and use of land when implementing land management policies (UNECE, 1996).

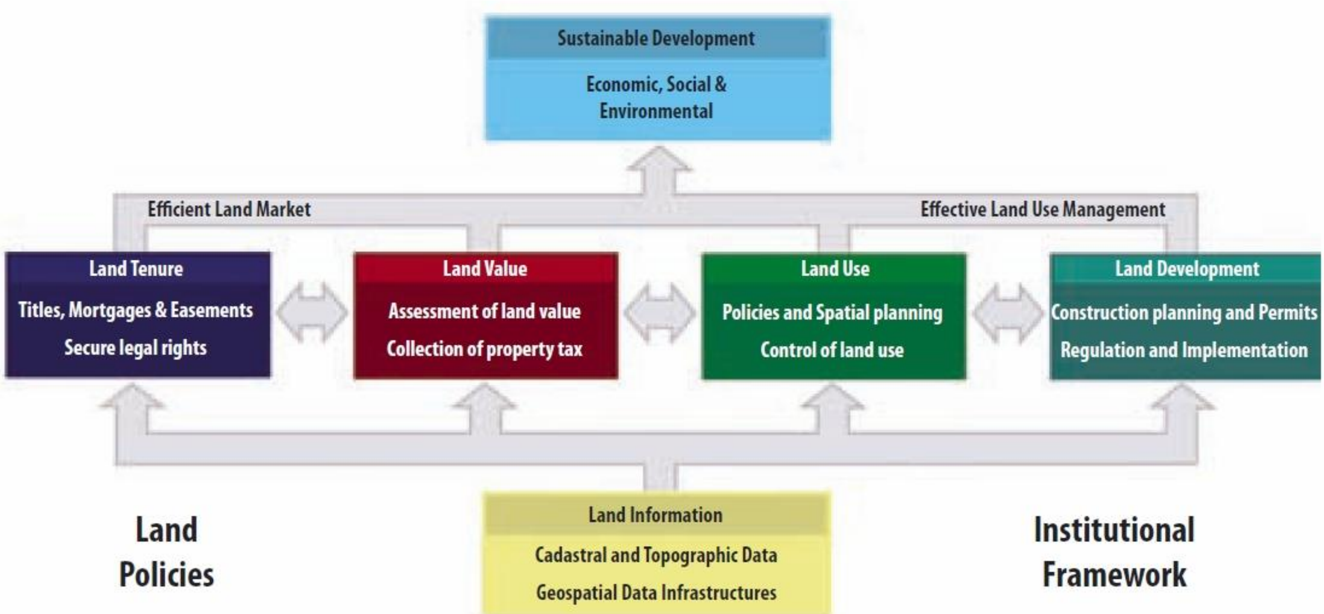


Figure 2-8: Land Administration Systems (source: FIG, publication No 47)

Many academics have investigated Land Administration and have contributed to various aspects of the field. Dale & McLaughlin (1999), Williamson (2001), Bogaerts *et al.* (2002) are just a few academics contributing to this field. Enemark (2009) underlined four functions of Land Administration: land tenure, land use, land value and land development, which play a principal role and which all countries have to handle one way or another [Figure 2.8].

It is generally recognized that the main targets of development in each country are generally defined by, among others, local history, ethical issues and governmental land policies that require proper implementation [Figure 2.9]. A well-functioning LAS is not only an indicator of local development and organization but reveals a civilized community as well [Figure 2.10].

Figure 2-9: Human poverty and environmental conservation are among the principal challenges of SDI (source: Maria Benaki, personal gallery, Cambodia 2014)

The Global Spatial Data Infrastructure association (GSDI, 2015) defines ***Spatial Data Infrastructures*** as "a coordinated series of agreements on technology standards, institutional arrangements and policies that enable the discovery and facilitate the availability of and access to spatial data". ***Spatial Data Infrastructures*** (SDI) is a general term, which includes the collection, maintenance, use and dissemination of spatial data, and was originally presented by Kok & van Loenen (2004). According to their publication, important aspects such as vision, leadership, communication strategy, coherence and intention of the geographic community to initiate new innovations play fundamental roles in terms of an organizational perspective in SDI development. Another quite similar, but more technical definition, was given by Grant (1999), who put forward that SDI

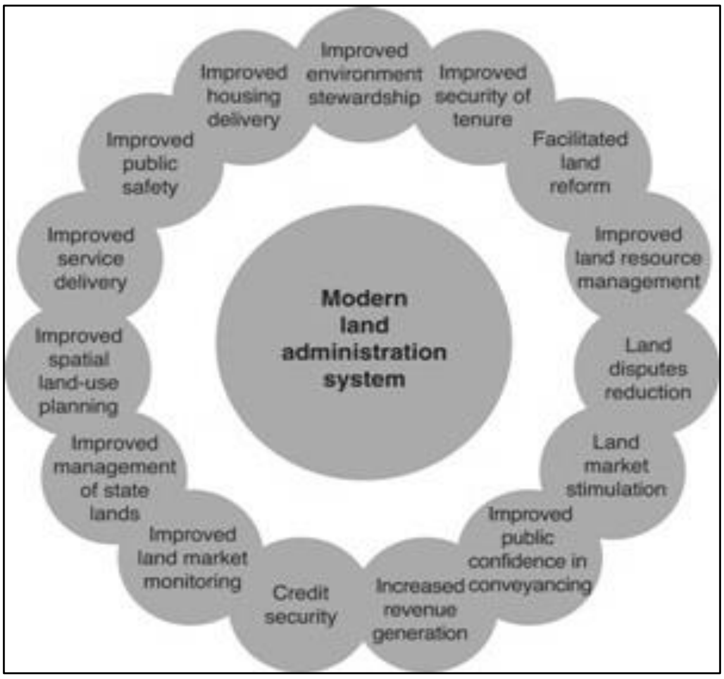


Figure 2-10: Modern Land Administration System (source: UNECE, 2005)

“in a geomatics framework provides mechanisms for sharing georeferenced information”. Ting & Williamson (2001) related SDI to land by referring to it as an invaluable information tool in the resolution of the ongoing tensions between people and land which makes another step in addressing human poverty and environmental conservation issues [figure 2.8]. Williamson & Feeney (2001) take a further step in that direction by mentioning that, “the growing importance of SDI and the land related skills are reflected in the re-discovery of the role that land administration plays in serving economic, environmental and social priorities in society”.

The infrastructure that serves Land Administration and is a sub-category of the general term Spatial Data Infrastructures has been termed Land Administration Infrastructure or simply Land Administration Systems. Enemark *et al.* (2005) gives the definition of a Land Administration System (LAS) as the “institutional framework which is complicated by the tasks that it must perform in terms of national, cultural, political, judicial and technical settings” and underlines that the “design of a LAS in western European countries was based on cadastral maps originally and services security of tenure and land valuation and taxation according to the use of land”. In other words, and in a more general framework, LAS is the basic tool for proper land management including the guarantee of ownership and security of tenure, fair taxation, security for credit, development of land markets, protection of land recourses, facilitation of state-owned land, reduction of land disputes, facilitation of rural land reform and improved urban planning (UNECE, 2005) [figure 2.9]. This is not a new concept and it has been developed in depth by Dale (2000) and Williamson (2001).

Its importance was again underlined by Williamson (2012) who has given three main characteristics of a proper LAS: it should be accurate, assured and authoritative – an ***AAA*** cadastral system. Responding to the more general principle of the “fit-for-purpose” approach in economics, Enemark *et al.* (2014) gives another view by introducing the ***fit-for-purpose*** principle into Land Administration, meaning that LA should be flexible, inclusive, participatory, affordable, reliable, attainable and upgradeable. According to a joint publication of FIG and World Bank (2014), the fit-for-purpose approach includes four keynotes. First, general boundaries may replace fixed boundaries especially in rural or semi-rural areas and their adoption may be sufficient for most land administration purposes. This perception was adopted in the creation of the interim cadastral maps within the experiments carried out in the practical part of this doctoral thesis. Secondly, aerial imagery can replace field surveys, especially if the satellite or aerial imagery is of high resolution. This simplification was also implemented in the cadastral compilation in the case study areas. Thirdly, accuracy relates to the purpose rather than the technical standards. In the experiments of this study, accuracy is addressed and proposals are given in order to improve the official process according to the available funds, technology and basemaps.

Cadastre is a significant part of Land Administration and has various definitions according to different scientific sources. The United Nations (in 1985) and the International Federation of Surveyors (FIG) (in 1995) gave the predominant definitions. The former underlines that “the cadastre is a methodically arranged public inventory of data on the properties within a certain country or district based on a survey of their boundaries; such properties are systematically identified by means of some separate designation. The outlines of the property and the parcel identifier are normally shown on large-scale maps" (UN, 1985). The latter notes, "A cadastre is normally a parcel based, and up-to-date land information system containing a record of interests in land (e.g. rights, restrictions and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, the ownership or control of those interests, and often the value of the parcel and its improvements. It may be established for fiscal purposes (e.g. valuation and equitable taxation), legal purposes (conveyancing), to assist in the management of land and land use (e.g. for planning and other administrative purposes), and enables sustainable development and environmental protection" (FIG, 1995). The need for an accurate and up-to-date cadastral system is so vital that Kaufmann & Steudler (1998), in their publication "Cadastre 2014", support the inclusion of public and traditional law aspects in the definition given by FIG in 1995.

Cadastral survey according to Steudler (2004) is "simply defined as a survey of boundaries of land units". Generally, cadastre is an essential tool for land management and administration as it records the land parcels which constitute a part of a country's spatial information infrastructure. The Bogor Declaration on Cadastral Reform (UN-FIG, 1996) in other words declared that the development of modern cadastral infrastructures facilitate efficient land and property markets, protect the land rights of all, and support long term sustainable development and land management. It also facilitates the planning and development of national cadastral infrastructures so that they may fully service the escalating needs of greatly increased urban populations.

2.4.1. Crowdsourcing techniques in Land Administration

The new era in LAS and the need to embed crowdsourcing techniques in its design is very recent. McLaren (2011) did research on LAS and crowdsourcing techniques with the sudden expansion of smartphones, focusing on unmapped areas and the great number of unregistered parcels worldwide. His findings showed that only 25% of land parcels have been formally registered in LAS (McLaren, 2011). Due to these two main controversial aspects, the universal trend has been towards a Public Participation Geographic Information System which "is a field of research that, among other things, focuses on the use of GIS by non-experts and occasional users" (Haklay & Tobón, 2003) and empowers GIS users to use technology purposefully to capture their local knowledge and advance their goals (Talen, 2000).

It is also remarkable that the number of megacities has risen from two in 1950 to twenty in 2005 while seventeen of them are located in the world's less developed regions (Doytsher *et al.*, 2010). More than 1.1 billion people live in slums, which are located in unregistered parcels (McLaren, 2011). It is clear that procedures should be made more efficient and the cost should be reduced through the involvement of individuals. As Adlington (2011) has underlined in the East Central Asia region, land reform and the land registration program has been completed by people without formal training in cadastral surveying. The project was guided by surveyors who were open to help without being wedded to traditional methods and high levels of accuracy.

It is clear that society's needs for easily edited and inexpensive maps which can be produced in short time has forced VGI in various fields. Land management, which mainly applies land information to land resources (UNECE, 2005), can flourish with the aid of VGI.

The main question that is posed in this research, taking into consideration all the above perspectives on technology and potential scenarios, is whether VGI and crowdsourcing techniques more generally can be incorporated in cadastral surveys and to what extent. The testing of the results is done through the Hellenic Cadastre project, which is a well-known, long-lasting project. The idea of incorporating VGI into the cadastral procedure is based on the power of locality and the participation of citizens in land planning as active parts of society.

2.4.2. Previous research and publications on VGI accuracy

The first step towards the assumption posed by this study requires consideration of accuracy. The innovation of the study is based on the fact that for the first time VGI is investigated regarding general cadastral processes. Previous research has focused on VGI accuracy for navigation or the theoretical idea of an OpenCadastre, however this study not only proposes a holistic model based on international research and trends but also tests it practically. Many researchers have expressed their doubts about the potential of using VGI in governmental projects although the trend leads in that direction. As Helbich (2010) has noted, important concerns and limitations affect spatial accuracy; the most important are technological bias, various data acquisition techniques and the subjective process of data acquisition.

Many researchers including the author have first focused their attention on evaluating VGI's accuracy in navigation. Haklay (2008), Ather (2009), Basiouka (2009), Kounadi (2009), Zielstra (2009), Ueberschlag (2010) and Kounadi & Basiouka (2010) are only few of the researchers evaluating the accuracy of OSM, the first crowdsourced map and which constitutes one of the most representative examples of spatial data derived from non-experts. The results were encouraging about the future of the specific data and its potential use. Moreover, Haklay *et al.* (2010) conducted further research proving that a reasonable number of volunteers per area can eliminate errors in mapping. All these studies were used not only as forerunners for the design of future projects but also exonerated and defined the real purpose of VGI.

Laarakker (2011) initiated an initial theoretical approach to introduce VGI in an alternative, open and flexible cadastral system by identifying the strengths and concerns over the success of this integration. He named his first attempt OpenCadastreMap, clearly introducing the need for an open system. The concerns are divided into two main categories: technical and socio-organizational. The technical include the quality control of OSM and OpenCadastreMap and the constructive technology; while the socio-organizational are focused on the necessity of the project, the role that the government will play in it, the legitimacy of control and the economic effects.

The major differences between VGI and the OpenCadastreMap techniques are focused on the contributors' interests, which are rather opportunistic than altruistic, and the standard exchange mechanisms that are adopted in the VGI environment, which are not as stabilized and well defined as the official cadastral agencies would prefer. The research raised operative and hierarchical differences concerning the maintenance and coordination of the volunteers and the GIS, which should be identified in a more detailed evaluation. The author concluded his approach by underlying that "there is not much difference between the uploading of the contours of a road and those ones of cadastral boundaries predicting a positive evolution of the idea". Since then, the research has attracted the interest of Navratil & Frank (2013) and De Vries *et al.* (2014) who investigated the term Neo-cadastres in an effort to explore the involvement of VGI within the traditional cadastral methods.

VGI has been incorporated in many applications worldwide due to the needs and challenges faced by nations and populations. However, there are still many concerns for its implementation in governmental projects for land administration purposes. For example Sui (2007) has declared that it is unlikely that VGI will make many of the conventional GIS practices of government and industry obsolete. More recent research carried out by Haklay *et al.* (2014) explored the potential of incorporating crowdsourcing applications in governmental projects and investigates real experiments conducted worldwide with volunteers.

2.5. Concluding remarks

The progress made in technology and mapping within the last decade is enormous and it is not easy for the research community to understand the great potential it offers in various academic fields. Since the advent of the WWW and static maps, the revolution has led to dynamic and mashup maps. Non-experts have also been involved in spatial data manipulation, which is translated in mapping based on easy-to-use web tools. It is clear that a new era in mapping has arisen and this results in a pluralism of thematic maps and a freedom of data and content. Crowdsourced data, which is free of charge, is not only easily collected and analyzed but also distributed by various parties, which means that it is strongly democratized. However, despite the revolution that has taken place in recent years, in Greece participatory mapping is still at an infant stage.

Current research identifies the spatial revolution and investigates the tools provided by VGI, the knowledge of web mapping and the expansion of dynamic maps and the global requirements for Land Administration. The interest of this research is focused on the incorporation of crowdsourcing techniques in the design of LAS and especially cadastral surveys, as an alternative to official procedures. Table 2.3 indicates the most important conclusions of this chapter.

➢ The web revolution has had a dramatic effect on mapping. Static maps have been replaced by dynamic and mashup maps, which offer a variety of applications and content.
➢ Content has been enhanced through a pluralism of thematic maps and data has been democratized with the aid of VGI.
➢ Crowdsourcing techniques and the VGI phenomenon have mobilized the research community to identify their parameters by investigating various

	terms and definitions. The importance of the phenomenon is demonstrated in researchers' increased interest.
➢	Another field that has evolved during the last decade is Land Administration, spatial data infrastructures and cadastral surveys, which impact on landownership, fair taxation and land use and development.
➢	The innovation of this research is based on the incorporation of crowdsourcing techniques within Land Administration and specifically in official cadastral mapping procedures.

Table 2-2: Concluding remarks of the second chapter

3. CROWDSOURCED EXAMPLES OF GOOD PRACTICE

3.1. Introduction

This chapter investigates successful case studies worldwide that have adopted crowdsourcing techniques in various circumstances. The various practical experiments are explored in depth and their main lessons are summarized at the end of each description. The research on the successful case studies was carried out by Haklay *et al.* (2014). The author undertook supervision by Haklay and worked on this project in cooperation with his team of experts. An investigation was made of the incentives, scope and aims behind the practical experiments; their participants and stakeholders; their relationships and the modes of engagement. The research also shed light on technical aspects, successful factors and the problems that were encountered in the evaluation of the examples.

Although the case studies are differentiated by content and scope, all of them are governmental projects that incorporate voluntary and crowdsourced data collection, so their study can isolate those components that are crucial for the success of the current project. The idea to associate governmental projects with crowdsourced techniques has also been given by Brabham (2013) who produced a report called "Using Crowdsourcing in Government", which outlines a more general overview of the potential for crowdsourcing in government. Brabham also attempts to classify crowdsourcing and understand when and how to deploy crowdsourcing in government.

Each case study is intended to provide an example of the use of VGI by government or by the public, and summarizes the context, positive and negative outcomes and main lessons. The focus of the case studies is divided into three main categories: land management, public administration and disaster response. Each category includes two main case studies and one supplementary case study, except for the last category, which includes three main case studies. The supplementary case studies are given separately in the next sub-chapter and they are not followed by separate main lessons. They do, however, provide similar findings to the main case studies and they are presented for reasons of completeness and understanding. All other main case studies are explored at a technical level, with their main story presented and the participants and actions given in detail. They all start with a table, which provides explanatory highlights of each case study in the format below:

Interaction type	The flow of the data (either crowdsourced or authoritative): **government→public, public→government, government→public→government, public→government→public**.
Trigger event	A specific event that might have triggered the data sharing (e.g. change in data license, natural disaster, etc.), where relevant.
Domain	The area in which the data sets have been used. This may include both an abstract characterization of the general area (e.g. generic mapping) as well as information about the specific field (e.g. update

	of National Topographic Database).
Organization	The organization(s) that initiated the data sharing process and those that have been actively involved in the whole project
Actors	Interested parties/stakeholders that have contributed to, or benefited from, the data sharing process in any way.
Data sets	The data sets that have been shared and used by the public or the authorities (including new data sets generated).
Process	The process followed to implement the data sharing, data integration and cooperation of VGI and authoritative data sets.
Feedback	The immediate result returned to the initiator of the data sharing process, if any.
Goal	The original goal of the project and reason for exploring crowdsourced geographic information.
Side effects	Any other issues or outcomes.

Table 3-1: Outline of each case study

Every case study includes the context, a description of the project and a discussion of the positive and negative aspects of the collaboration. The stories end with bullet points indicating the most important lessons to be learnt from each example. Ten case studies are explored in total.

The table 3.2 indicates the main components of the third chapter.

➢ Ten crowdsourced examples are presented in detail and their main components are given. Emphasis is given to the sociological and technical keynotes of each application.
➢ The content of the case studies is divided into three main categories: land management, public administration and disaster response.
➢ Main lessons as interesting outcomes of each case study are summarized at the end of every case study and are used as forerunner for the corresponding cadastral model proposed by this study. The main lessons are given in bullet points.
➢ Technical aspects are also explored in depth as generalized findings because they play a fundamental role in the design of every crowdsourced experiment.
➢ Successful factors constitute the last part of the chapter and these can be incorporated in every crowdsourcing effort depending on its nature.

Table 3-2: Predominant components of the third chapter

3.2. Short description of the case studies

Before the analysis of each case study, a short description that can shed light on each governmental crowdsourced project is given briefly. The story behind each experiment and its content is presented in this section. The first three case studies constitute examples of land management, the next three examples of public administration and the last four examples of disaster response. Each section contains two main cases studies and one supplementary case study, which is not analyzed in depth as it bears great similarities to the other two, except for the last category which contains three main examples and one supplementary example.

Mapping of South Sudan. This was launched because of the need for a temporally accurate and up-to-date map when the new nation was created. Google Map Maker, the Sudanese diaspora and various organizations carried out workshops to train people to work separately on the digitization of aerial imagery. A significant amount of work was completed in a very short amount of time by adopting local knowledge and providing technical tools. Those who experienced the training sessions were inspired to transmit the experience and recruit new volunteers.

Informal settlement mapping, MapKibera, Nairobi, Kenya. Map Kibera was carried out in the most crowded slum in Nairobi, Kenya, in an effort to improve its reputation and offer an accurate picture of the area, which is quite dynamic due to the movement of the population. Local people collected and edited GPS tracks. Innovative techniques such as SMS, video and voice reporting were also launched and a small amount of compensation offered to participants.

Shelter Associates, slum mapping in India. Shelter Associates is an NGO focused on housing projects, sanitation, health and education initiatives in India. It uses slum mapping to promote good governance and decision making policies. It is a hybrid model with expert and local volunteer contributors and has used GIS since late 1990s, recently introducing Google Earth as an easy-to-use tool for informal settlement mapping.

Crowdsourcing The National Map, National Map Corps, US. National Map Corps has given volunteers the choice to collect and edit data about ten different human-made structures in fifty states in an effort to provide accurate and authoritative spatial data. The methodology includes various steps such as adding new features, removing obsolete points and correcting existing data. A pilot test in Colorado showed that the VGI was satisfactory in its accuracy.

iCitizen, mapping service delivery, South Africa. This project is at the design phase and aims to involve the public at a local level to collect data points via mobile phones and adopt different ways for geotagging of photos in real time or via SMS and email. The purpose is to report infrastructure issues.

Twitter use in Italian municipalities. A research project into the profile, activity and use of Twitter accounts of Italian municipalities, the study focused on the types of messages sent, revealing that culture and tourism are the most common topics. Twitter also provides opportunities for members of the public to communicate with municipalities.

Haiti disaster response. One of the most well-known crowdsourcing applications, developed after the earthquake hit Haiti in 2010. Within 48 hours, the capital was mapped by volunteers who contributed from every part of the world to create an up-to-date topographic map to fill the gap left by the official mapping agency. The maps were used by various organizations to allocate supplies and medicine.

Community Mapping for Exposure in Indonesia. The goal of this project is to reduce vulnerability to natural disasters. Young people have successfully collected spatial and attribute data, and traced them in the OSM platform so that thematic maps can be created to show potential damage in case of physical disasters.

Flood preparedness through OpenStreetMap, Jakarta, Indonesia. A sub-category of Community Mapping for Exposure, in this project the heads of villages in the area of interest were asked to identify their critical infrastructure by using paper maps and university students entered the information into OSM. The data can produce maps for disaster risk planning.

Crowdsourcing satellite imagery in Somalia. The project was launched in an effort to map all shelters that are located in the Afgooye corridor, Somalia, to identify the number and location of refugees. Satellite imagery was used to map the information in order to facilitate decision making policies.

3.3. Crowdsourced case studies in land management

The next two case studies investigate land management in two areas with informal settlements and extended areas of slums, to consider what challenges these areas face in terms of mapping. Both experiments concern poorly mapped areas that require up-to-date general topographic maps and thematic maps of essential features and face severe economic problems to finance those incentives.

3.3.1. Mapping of South Sudan

Interaction type	**Public→Government→Public**
Trigger event	On 9 July 2011 South Sudan became Africa's 54th nation after its official independence. Although it is the newest nation, it is poorly mapped.
Domain	Generic mapping of a poorly mapped area and thematic maps of essential features like roads, hospitals and schools.
Organization	Google, NGO organizations along with the World Bank, United Nations Institute for Training and Research (UNITAR), Operational Satellite Applications Programme (UNOSAT) and Regional Center for Mapping of Resources for Development (RCMRD).
Actors	The Sudanese diaspora, Google, the World Bank, UNOSAT and RCMRD.
Data sets	Updated satellite imagery covering 125 000 km^2 (40% of the UN's priority areas) uploaded to Google Earth and Maps.
Process	Workshops and editing on Google Maps via Google Map Maker.
Feedback	Generic and thematic maps covering important points of interest such as schools, hospitals and roads.
Goal	To engage and train the Sudanese diaspora and other volunteers worldwide to participate in Google Map Maker.

Side effects	Mapping the poorly mapped South Sudan so that the infrastructure and economy of the country could be developed and humanitarian aid provided to the local population.

Table 3-3: Summary of Mapping in South Sudan

After years of political instability, South Sudan became a new nation on 9 July 2011 after its official independence. Although South Sudan is expansive and the newest nation, it is poorly mapped. Maps are particularly important for the development of the infrastructure and economy of the country and the distribution of humanitarian aid (IT News Africa, 2011).

Google, with the aid of World Bank, UNOSAT and RCMRD, recognized this need and started the project for the creation of better maps of South Sudan by supporting communities to map schools, hospitals, roads and more with the Google Map Maker. (Lamy, 2011b) The project was launched with a series of events to disseminate the purpose of the mapping and inspire and train participants. The first event was in April 2011 at the World Bank headquarters in Washington, DC, with a satellite event in Nairobi at the same time. The next event was in September 2011, held by the South Sudan National Bureau of Statistics in Juba (Google Site, 2014) [Figure 3.1.].

Figure 3-1: Satellite event in Juba (source: Google Site, 2014)

To aid their work, updated satellite imagery of the region, covering 125 000 km^2 (40% of the UN's priority areas), was uploaded to Google Earth and Maps (Lamy, 2011c). In the last event volunteers worked together and made hundred of edits in less than four hours. The process is simple: citizens edit using available web tools and their local knowledge and, after approval, edits become visible to all Google users worldwide. The mapping was used by the Satellite Sentinel Project, a collaborative project focused on human rights violations and human security concerns in Sudan and involving Google, the Enough Project, Not On Our Watch, UNITAR, UNOSAT, DigitalGlobe, the Harvard Humanitarian Initiative and TrellonAmong (Brown, & Heaton, 2011).

Among the main factors for the project's success is not only the enthusiasm and inspiration of the Sudanese diaspora, which encouraged them to convey the experience and knowledge to other people, but also the interest that the local government showed in the project (Lamy, 2011a). The project's approval by local government and its impact in decision making policies is noticeable. Another innovation of the project is the principal role and contribution played by the Sudanese diaspora. Through VGI projects, local knowledge can be shared worldwide and from different parts of the planet, not only from the area of interest. At the same time, among the main weaknesses of the mapping is that local people were not actively involved. The project lacked research in the field, and did not use GPS or open source software, although Google's involvement guaranteed great participation levels.

Main lessons:

- Crowdsourcing projects can be coordinated and implemented from a distance.
- Great participation of volunteers and transmission of motivation to others are key factors in terms of participation in crowdsourcing applications.
- Inspiration for other projects and improved applications can be beneficial to areas of interest.
- Acceptance by local government as an opportunity for decision making policies and humanitarian aid can escalate the impacts of a VGI project.

3.3.2. Informal settlement mapping, MapKibera, Nairobi, Kenya

Interaction type	**Public→Government→Public**
Trigger event	-
Domain	Generic mapping of the biggest informal urban settlement area and thematic mapping of security, water sanitation, health and education.
Organization	Map Kibera.
Actors	Map Kibera team, CfK (Carolina for Kibera), GOAL, USIP, Indigo trust, ATTI, Habitat, Global Giving, Plan Kenya, Hivos, Unicef, JumpStart International, Ushahidi, SODNET (Social Development Network), KCODA (Kibera Community Development Agenda).
Data sets	GPS tracks, open source and conventional software.
Process	Collecting GPS tracks and tracing them in OSM platform after training workshops.
Feedback	Topographic and purpose-built maps for the management of supplies in health, education, security and water sanitation.
Goal	Map the unmapped Kibera and actively involve local people.

Table 3-4: Summary of Informal Settlement Mapping in Nairobi, Kenya

The homepage of the project (MapKibera, 2014) welcomes the visitors by stating that "Kibera in Nairobi, Kenya, was a blank spot on the map until November 2009, when young Kiberans created the first free and open digital map of their own community". The welcome message summarizes the main idea behind the project, which is to map one of the biggest informal settlements of the world by putting marginalized communities on the map.

Map Kibera was launched in 2009 by Mikel Maron and Erica Hagen with initial funding by Jumpstart International, an NGO specializing in community-based mapping. The first phase, which lasted three weeks from October to December 2009, involved 13 young people who were trained to collect and edit GPS tracks. OSM was used to create a dynamic and easily edited map and QGIS software was adopted to do further analysis and create specialty maps (Marras, 2012). ArcGIS, a non-open source software, and Tile Mill and other MapBox products were also used.

The second phase of the project (February to August 2010) offered the opportunity for mappers to enhance points of interest such as water, public toilets, schools, police stations and clinics (Hagen, 2010). It also included two other mini projects: the Voice of Kibera and the Kibera News Network. The first offered the opportunity to submit reports, write articles and add breaking news with the aid of Wordpress blogging and Ushahidi software. Work could be sent by SMS and published after approval by an editorial team. The second is a video journalism initiative offering more locals the opportunity to participate and to ensure the wider acceptance of the project and hence its longevity (Hagen, 2012).

Among the main successes is the project's acceptance by local government, which embraced it from the beginning. At the end of the project, Map Kibera representatives presented the analysis to government officials. The negotiation between the two sides had a positive impact for the community, which became recognized as a real neighborhood, and residents gained new technological knowledge.

The project faced various challenges, the primary being to educate residents in new technologies. The voluntary participation model was unrealistic in Kibera. Locals suffer great survival issues so a small daily compensation was given for their participation. Residents also found it hard to understand the benefits they could gain through participation and the general potential impact of the project. Finally, NGOs found it difficult to cooperate and share information. They had learned to work separately and competitively for a long time, which meant that voluntary work was splintered off into small pieces, for different purposes [Figure 3.2.].

Figure 3-2: Map Kibera member Zack Wambua shares the map with Maono Secondary School (source: MapKibera blog, 2014)

Main lessons:

- Slum mapping can be achieved by young local people relatively quickly.
- Basic topographic maps can be enhanced with essential thematic layers.
- A combination of open source and conventional software can facilitate VGI projects.
- Compensation may be needed to improve participation in locations where participants suffer great survival issues.
- Innovative methods such as SMS, voice and video reporting can support the appeal of mapping projects.

3.4. Crowdsourced case studies in public administration

The next two case studies consider the approval of local administration in design and they are supported financially. The two experiments were carried out in developed countries and counter the assumption that only developing countries require voluntary participation in governmental projects.

3.4.1. Crowdsourcing The National Map, National Map Corps, US

Interaction type	**Public→Government→Public**
Trigger event	The need to update the national map and other national map databases.
Domain	Generic mapping.
Organization	US Geological Survey (USGS), National Geospatial Program.
Actors	Local, state and federal agencies including the USGS.
Data sets	USDA National Aerial Imagery Program (NAIP) Imagery, National Map base layers, ESRI world imagery, Alaska community photos, the national structures database and USTopo.
Process	Using crowdsourcing techniques, the USGS's National Map Corps

	encourages public volunteers to collect and edit data about human-made structures to provide accurate and authoritative spatial map data for the USGS National Geospatial Program's web-based National Map.
Feedback	Updated structures are contributed in real-time. Databases are downloaded on a nightly basis. Data collected is in the public domain and freely downloadable.
Goal	Maximize limited resources while continuing to support the National Geospatial Program by leveraging volunteers with local knowledge to update The National Map and USTopo.

Table 3-5: Summary of the National Map Corps US project

VGI is not new to the USGS, but past efforts have been hampered by available technologies. Over the past two decades, the USGS has sponsored various forms of volunteer map data collection projects, including the Earth Science Corps where volunteers annotated topographic paper maps, the collection of GPS points using handheld GPS devices and, finally, web-based technology to input data in 2006. In spite of these efforts, and as valuable as the updates were, technology could not keep pace with decreasing USGS resources, and the VGI effort was suspended in 2008. Today, the perfect storm of improved technology, social media and ever decreasing resources has once again made crowdsourcing an attractive option.

Figure 3-3: The interface of the Map (source: Elizabeth McCartney)

After several pilot projects to determine the viability of bringing back the volunteer mapping program, The National Map Corps volunteers are successfully editing ten different structure types in all fifty states, including schools, hospitals, post offices, police stations and other important public buildings [Figure 3.3.]. Using National Agricultural Imagery Program (NAIP) imagery as the primary base layer, volunteers collect and improve data by adding new features, removing obsolete points and correcting existing data. Edits are contributed through a web-based mapping platform built using open source technology developed by OSM. Points edited are incorporated into The National Map and ultimately become part of USTopo.

In order to address quality concerns, an analysis of a pilot project was conducted over the state of Colorado. For all structure feature types, volunteer involvement was found to improve positional accuracy, attribute accuracy and reduce errors of omission. The Colorado pilot demonstrated that volunteer edits improve our baseline structures data; that further review by advanced volunteers willing to provide peer review improves the data further; and that sample-based inspection by USGS personnel can monitor these processes.

Successful crowdsourcing is not without challenges, some of which include volunteer recruitment, volunteer engagement and participant motivation. The National Map Corps endeavors to meet these challenges using gamification techniques and a mixture of traditional and social media. Gamification includes easy on-ramping, virtual recognition badges, friending, map challenges, social media interaction and a tiered editing approach. Using these techniques has been successful. The National Map Corps continues to see substantial increases in the number of volunteers and volunteer contributions to The National Map.

Other challenges continue to exist and include: organizational resistance to accepting data from volunteers as being "good enough" to populate national databases; and working through issues for which there is no well-established policy regarding government accepting data from citizens. One example is the requirement to obtain approval for conducting a "survey" from the Office of Management and Budget as part of the Paperwork Reduction Act even though the project is not really conducting a "survey". (Mrs. Elizabeth McCartney, 2014, pers. comm., 16 May).

Main lessons:

- Adoption of challenging techniques such as gamification has been successful and attracts volunteer interest.
- Evaluation of the quality indicated that the participation improves accuracy and reduces the errors.
- Organizational resistance to accepting data from volunteers is one of the major challenges for VGI projects of this kind.
- Key factors to successful crowdsourcing include building on past experience, leveraging existing technology and having the support of key individuals within the organization.

3.4.2. iCitizen, mapping service delivery, South Africa

Interaction type	**Public→Government**
Trigger event	-
Domain	Generic mapping with focus on local infrastructure issues.
Organization	University of Witwatersrand, LINK Centre.
Actors	LINK Centre.

Data sets	Multiple data sets per service delivery issue to be tracked.
Process	Collection of data points via mobile phones. Adoption of different ways of geotagging photos in real time or via SMS or/and email.
Feedback	Generic and purpose-built maps for disaster preparedness.
Goal	Reporting and solving fundamental problems with basic infrastructure and services.

Table 3-6: Summary of iCitizen mapping service delivery in South Africa

In recent years, South Africa has seen a surge in political protest against slow service delivery. While the United Nations' Human Development Index considers South Africa to be a middle-income country, there is a large disparity in income distribution across the population. Social unrest is an obvious consequence of poverty, high levels of unemployment and service delivery backlogs.

Within the context of these issues a new initiative has been launched, which intends to improve the daily life of citizens by collecting crowdsourced reports of service issues and passing them to the relevant authorities for resolution. The iCitizen project will give citizens the ability to report on fundamental problems with basic infrastructure and services [Figure 3.4.]. The researchers involved in the project intend to contact local municipalities to discuss the extent to which this project can be embedded within current initiatives around citizen monitoring and evaluation. The main aim of the project is to give citizens an active voice. A secondary research objective is to understand and identify the role of mobile phones in citizen-led monitoring and evaluation.

Members of the public will be able to report issues by forwarding geotagged photographs, sending in locations via SMS or reporting issues via email. The first iteration of iCitizen was built upon the Drupal open source content management system (CMS). As an enterprise CMS, it provided a lot of services out of the box, including membership management, image upload, taxonomy (category) management, user commenting, thorough user permissions, field APIs, views templating and reporting and HTML5 theming capability. Researchers were able to extend the core functionality to include mapping enabled through geolocation, leaflet maps (using OSM as the Map Tile server) and a voting API allowing users to verify incidents.

The designers of the application will be extracting boundary data for South African provinces, districts and local municipalities and exposing these on the online map using GeoJSON data. This will automate the process of calculating the jurisdiction of any reported incidents. A live reporting engine and online social tool will also allow for two-way communication between the web server (and its user-base) and local municipalities and civil societies.

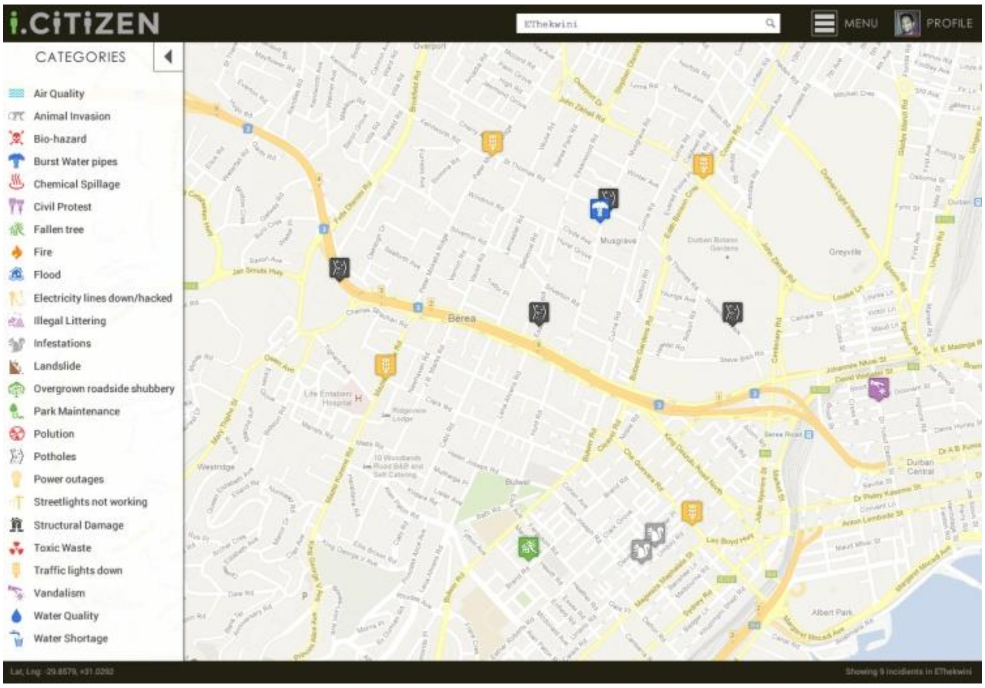


Figure 3-4: The interface of the Map (source: Kiru Pillay)

The main difficulty relates to the acceptance of the project. One university found validity in the concept but was unable to commit resources for the development of the application. Going forward, two difficulties are envisaged. The first is acceptance of the validity of the generated data sets by local municipalities. The second is acceptance of the use of mobile phone and applications by the public as an effective tool for voicing service delivery concerns. Even though the penetration rate of mobile phones is fast approaching 100% of the adult population in South Africa, the use of mobile applications and GIS-mapping tools of this nature is largely untested (Dr. Kiru Pillay, 2014, pers. comm., 14 May).

Main lessons:

- Projects can be used for a variety of tasks at local level, not just that for which they were designed.
- Using a range of software, programming languages and platforms can broaden a project's horizons.
- VGI applications face financial issues due to their technological nature and the resources of the organizations involved.
- Concerns from agencies about the quality of generated data sets and improving public adoption of mobile applications are common challenges.

3.5. Crowdsourced case studies in disaster response

The last section contains successful case studies that flourished as a consequence of disaster response. The first example concerns the first and most predominant crowdsourced a posteriori action, and the other two concern characteristic examples of a priori preparedness. The last example has adopted the a posteriori response as well.

3.5.1. Haiti disaster response

Interaction type	**Public→Government→Public**
Trigger event	A natural disaster (earthquake) and humanitarian crisis.
Domain	Generic mapping (topographic maps of the area) / purpose-built maps (disaster relief management).
Organization	Humanitarian OSM Team (HOT)
Actors	United Nations, NGOs, National Haitian Mapping Agency, National Center of Spatial Information, Haitian civil society.
Data sets	Historic maps, CIA maps, high-resolution imagery from Yahoo, paper maps and GPS tracks.
Process	Tracing in OSM platform from different data sources and collecting GPS tracks.
Feedback	Topographic and purpose-built maps for the management of supplies of medicine and food, and location of settlements.
Goal	Facilitate disaster response management.
Side effects	The data sets created have not been used by the national mapping agency (NMA) but by international aid organizations (UN, USAID).

Table 3-7: Summary of Haiti disaster response

Haiti was dramatically affected after a 7.0 magnitude earthquake hit the capital city of Port-au-Prince on 12 January 2010. Death toll estimates range from 100,000 to 200,000. More than 250,000 residents were injured and more than 30,000 buildings collapsed or were severely damaged. When the magnitude of the disaster became clear, the main issue for those responding to the disaster was that the only available spatial data were poor and last updated in 1960s. The local mapping agency collapsed in the earthquake, with the loss of most of the skilled employees. An updated map was urgently needed for the distribution of supplies, identification of collapsed buildings, damaged infrastructure and medical stations. This catastrophe was characterized by the experts as an engineering problem in the most extreme environment (Maron, 2010a).

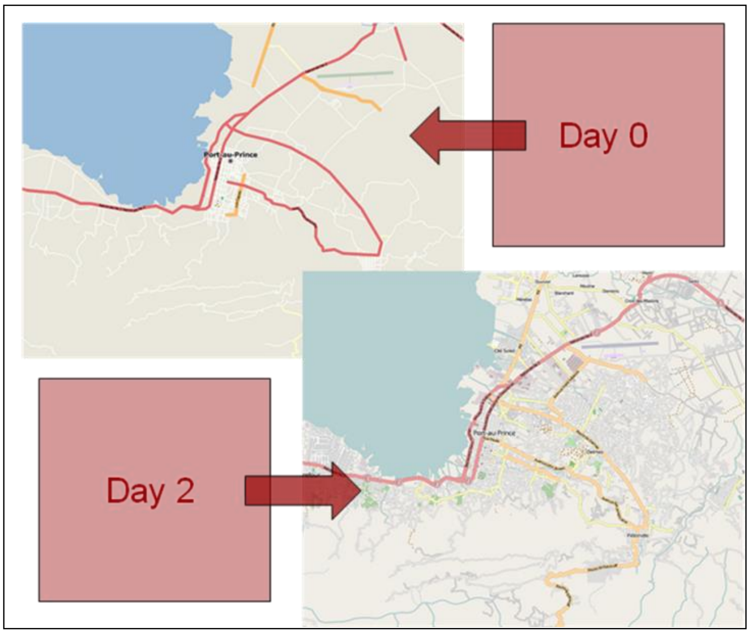


Figure 3-5: The process of the mapping within 48 hours (source: OpenStreetMap)

The Haiti disaster response is one of the successful examples of geographic information being made open by official partners, enhanced by public volunteers and returned to government for action (although the government was reluctant about the involvement of volunteers). The first imagery was loaded on the OSM platform in 48 hours (Maron, 2010b) [Figure 3.5.]. 60 people were trained and more that 700 contributed to the mapping, among them people from UN agencies, NGOs, National Haitian Mapping Agency, National Center of Spatial Information (CNIGS) and Haitian civil society (Waters, 2010). Historic maps, CIA maps and high-resolution imagery from Yahoo were first used for tracing in OSM to improve the basic maps (Haklay, 2010a). Volunteers with paper maps and GPS completed the second phase of tracing. The effort led to the PDNA (Post Disaster Needs Assessment), the result of the analysis of satellite and aerial imagery by multiple sources, in which more than 30,000 damaged infrastructures were identified and classified. According to HOT, 600 volunteers added spatial information to OSM in a month and the result was used as a default basemap for responding organizations and the Haitian government.

The main reasons for its success can be focused on four main factors; time, cost, great participation of volunteers and official trust. The sensitization of the public to the Haitian crisis led to a great participation of volunteers and immediate mobilization worldwide. The contribution of NGOs and other official partners and the release of conventional data sets as reference maps for tracing without licensee restrictions were vital to success. Government support was inevitable due to the critical circumstances and limited resources.

Although, the project is characterized as successful, there were a few weaknesses. On the one hand, all the responding organizations lacked experience and awareness of the operational norms in humanitarian response, which constitute an operational framework for the accountability of different sources. On the other hand, deficiency of coordination led to the duplication of data. Also, the national mapping agency CNIGS never really engaged with OSM although official data were given supportively at the beginning of the project.

Main lessons:

- This was the first crowdsourced mapping exercise for humanitarian reasons and shows its successful use in reacting to disaster.
- An integrated methodology of this kind follows four steps: spatial data contributed by official providers, supplemented with GPS tracks, integrated into OSM and updated by a great number of volunteers from each part of the world.
- Time, cost and official trust of data by NGOs and other official partners are key to success.
- Lack of coordination and experience between different actors can lead to duplication of data and waste of resource.
- Differentiation between conventional and governmental data in terms of engagement to the project did not prevent success.

3.5.2. Community Mapping for Exposure in Indonesia

Interaction type	**Government→Public→Government**
Trigger event	-
Domain	A priori disaster response.

Organization	Community Mapping for Exposure in Indonesia.
Actors	Indonesian Disaster Management Agency (BNBP), Australian Agency for International Development (AusAID), Humanitarian OSM Team (HOT), Civil Society Strengthening Scheme (ACCESS), the World Bank Global Facility for Disaster Reduction and Recovery (GFDRR).
Data sets	Satellite imagery, GPS tracks and attribute data.
Process	Collecting spatial and attribute data and tracing in OSM platform.
Feedback	Thematic maps showing damage in case of various physical disasters.
Goal	Reduction of vulnerability to natural disasters.
Side effects	Deemed as a successful example of disaster relief preparedness that could be applied in other developing countries.

Table 3-8: Summary of community mapping for exposure in Indonesia

An example of an a priori disaster response, the Indonesian mapping project began in early 2011 (OpenStreetMap Indonesia, 2012a) and at the time of writing is still active following an initial three-month pilot period. The main idea behind the project was to use OSM to collect previously unavailable data about buildings and their structure in both urban and agricultural environments and to use appropriate models to calculate likely damage in case of physical disaster. The combination of the impact models and the use of realistic data led to the development of an open source risk modeling software (InaSAFE) showing the affected people, infrastructure and damage if disaster were to hit a specific area. This offers a practical tool for governments to develop actionable contingency plans and fills the need for risk assessments identified by the World Bank (GFDRR, 2013).

The pilot phase consisted of workshops offering training on the project and building construction as well as data collection in urban and rural areas. The approach between rural and urban areas was slightly different, although the result was similar. The original data were derived from paper maps, which were edited by local people; satellite imagery depending on the availability; and GPS tracks. Data were edited using JOSM and Potlach2 web editor and then used in QGIS (Chapman *et al.*, 2013). Urban areas were mapped by students who took part in a mapping competition. Rural areas were mapped with ACCESS contributors and local people. The second phase lasted from July 2012 to March 2013 and focused on collecting exposure information essential for impact modeling software (Humanitarian OpenStreetMap Team, 2013). In total, 163,912 buildings were mapped during the pilot, 29,230 in urban areas, 16 workshops were held with 124 people participating in rural areas and 5 universities in urban areas [Figure 3.6.].

To encourage participation, Community Mapping for Exposure has a pyramid format based on leadership, with specific guidelines in data manipulation and great coordination between different contributors. The whole process is focused on workshops, participants were supervised at many stages and the procedure of data collection and manipulation was firmly defined. Motivations for participation varied, with incentives covering a spectrum from disaster protection to mapping competition. In terms of technical support, the whole project was not only supported by HOT and OSM but also by open source software such as QGIS. The main innovation in data collection was the private datastore, which offered a unique ID for each object. The final output has also been a success in enabling local government to visualize where people are most in danger by combining local wisdom with scientific knowledge to produce realistic scenarios for numerous different physical disasters.

Figure 3-6: Community Mapping for Exposure in Indonesia (source: Akhadi, 2014)

The main aspect of concern is the quality of the results, which showed great variation. According to the final report, the quality was either very bad or very good in different areas, although it was found as acceptable generally. The attribute quality, which has a principal role in the success of the project, indicated a great number of empty or incorrect records concerning the structure of buildings (OpenStreetMap Indonesia, 2012b). Other minor deficiencies were also noticed, such as failing to create constant mapping volunteers and the use of time-consuming technical methods in a few cases (e.g. Excel spreadsheets in data collection or manual methods of data manipulation).

Main lessons:

- An a priori disaster response can be focused on appropriate models and parameters and can calculate damage in case of a physical disaster by using VGI.
- Interaction between official providers and VGI is a parameter of success not only for the beginning of the project but also for its continuity.
- Open source data can be reliable for scenario building but its quality can vary,

especially in terms of attribute data.

- Risk managers, local communities and the public can combine local wisdom with scientific knowledge to produce realistic scenarios for numerous different physical disasters that may occur in an area of interest.
- The coordination of participating organizations and volunteers is important to take full advantage of human resources and technical innovations.

3.5.3. Flood preparedness through OpenStreetMap, Jakarta, Indonesia

Interaction type	**Public→Government→Public**
Trigger event	Disaster management agency of Jakarta wanted to have better data for flood planning and reporting.
Domain	Mapping for disaster preparedness.
Organization	Jakarta Disaster Management Agency (BPBD DKI Jakarta).
Actors	Australia-Indonesia Facility for Disaster Reduction (AIFDR), United Nations Office for Coordination of Humanitarian Affairs (UNOCHA), Humanitarian OSM Team (HOT), University of Indonesia (UI).
Data sets	OSM data of neighborhood boundaries (*Rukun Warga*), religious, health, sports and government facilities, schools, roads.
Process	The heads of Jakarta's 267 urban villages were asked the locations of their critical infrastructure, which was then mapped by university students from the University of Indonesia and entered into OSM.
Feedback	Urban village leaders received paper poster maps of their villages for their participation.
Goal	Improve geographic information of Jakarta available for flood planning.
Side effects	Having a detailed basemap of Jakarta has made others interested in the idea of crowdsourcing and using community mapping to collect base data and record event data at a relevant scale.

Table 3-9: Summary of flood preparedness through the OSM in Jakarta, Indonesia

Jakarta, Indonesia, is a large megacity that has frequent seasonal flooding issues. Jakarta's disaster management agency (BPBD DKI Jakarta) needed better data to prepare for the flood season. AIFDR, UNOCHA, HOT and University of Indonesia assisted in the process (OpenStreetMap Indonesia, 2014).

The original idea was to ask the heads of the 267 urban villages the location of their critical infrastructure, then ask university students to help with technical issues. Impact analysis using InaSAFE (open source impact modeling software) was then performed as part of a contingency planning process, and the data has been used to create government maps to report flooding conditions and the village heads have used their poster maps to plan logistics when responding to flooding.

The project also created an open data set that can be used for a variety of analysis at the village, district and provincial levels. Using an open platform means that anyone can use the data and it can be updated easily as the information becomes outdated. The data collected has been useful in both the 2013 and 2014 floods, allowing the government of Jakarta to show more detailed maps than previously available and increasing demand for additional mapping at a higher resolution.

One negative aspect of the methodology used is that while it did collect the data very quickly, the urban village officials do not have an easy way to update their area as the data changes.

Main lessons:

- Collaboration between different teams of local people, depending on their knowledge, means participants can contribute to specific tasks and stages of the project.
- Open data can be used at different levels of decision making policies such as village, district and provincial levels.
- Difficulty in keeping data up to date is one of the most important concerns in terms of viability.
- Data can be used in a variety of ways, including by governmental bodies for the creation of maps.

3.6. Supplementary case studies

The last three case studies work supplementary to the above three main categories and provide the same main lessons and conclusions. The first case study falls under land management, the second under public administration and the last under the disaster response category.

3.6.1. Shelter Associations, slum mapping in India

In urban areas of India the percentage of citizens who live in slums fluctuates from 10-50%, which means that a great number of people lack basic infrastructure and housing. Housing, health, sanitation, education and livelihood are among the main issues that NGO Shelter Associates tries to address in specific areas of India through a variety of projects intended to improve the living conditions of slum dwellers (Shelter Associates, Research and Poverty Mapping, 2014). Shelter Associates was established in 1993 by architects and planners and works in direct collaboration with the local government for the improvement of citizens' lives. It has adopted a hybrid model of experts in various academic fields, such as GIS analysts, sociologists, planners and architects, who work with the aid of local volunteers. The volunteers contribute to slum mapping by maintaining up-to-date data for informal settlements and supporting community participation in other projects carried out by Shelter Associates (Shelter Associates Home Page, 2014).

According to Shelter Associations, the main issue that local government faces is the lack of local knowledge about the spatial infrastructure of slums, which results in the exclusion of informal settlements from city planning and urban development. The local people consider mapping as an opportunity to move to other areas where schools are located or to save money by adopting better transportation routes.

Shelter Associates pioneered the use of GIS for poverty mapping in the late 1990s (Shelter Associates, GIS and Remote Sensing, 2014). However, in recent years, the need to connect the data collected for the various projects, and stored in different layers alongside spatial information, became crucial. The team adopted Google Earth as a basemap for the slum mapping and among other benefits, Google Earth is easy to use, easy to understand because it includes aerial images and offers a clear picture of development within the city. The spatial data was introduced into a variety of projects to support good governance and decision making policies.

3.6.2. Twitter use in Italian municipalities

Research investigating the Twitter profiles of Italian municipalities identified that, at the time of the survey (November 2013), only 461 of more than 8,000 Italian municipalities had Twitter profiles, approximately 6%. After a few months, this increased to about 25% while six months before, only 368 municipalities retained a Twitter account. The geography of municipal profiles in Italy seems to reflect the urban structure of the country, which is mostly made up of many small and medium sized cities. At the time of the survey, only 1% of the 461 profiles had been activated by large municipalities, 4% by medium municipalities, 44% by small to medium municipalities, while 51% had been activated by municipalities with less than 10,000 inhabitants.

This demonstrates that reduced population size is not a barrier to the spread of social applications but may in fact be an advantage or a driver. The first and the most active (in terms of tweets sent and followers) municipalities on Twitter are those that started with the activation of "civic networks" (municipality websites) in the late 1990s, showing the relationship between these kinds of technologies.

The survey has analyzed the types of messages sent, since the activity profiles must be assessed not only in relation to the amount of tweets and followers but also with respect to the quality and type of information sent. The latter relate to different fields, which include simple messages for informational purposes up to the more complex addressing issues that affect planning and territorial management. The research team classified the hashtags used by most municipal profiles into several categories and the

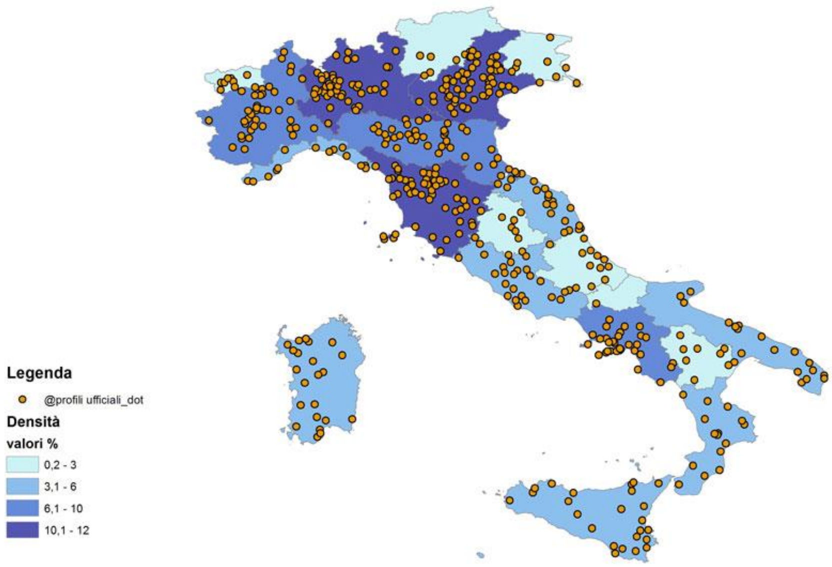


Figure 3-7: The density of the Twitter profiles on the map (source: Cristina Capineri)

most widely represented information related to culture and tourism, followed by geographical information, utilities and weather forecasts [Figure 3.7.]. Messages about governance are still quite limited except in some cases, demonstrating that the potential of Twitter as a collector and distributor of information on complex issues around which to initiate debates and discussions has not been realized. Only a few municipalities have used Twitter for emergency and risk management, such as Castelnuovo Garfagnana (earthquake) and some municipalities in Sardinia (flooding). Nevertheless it is worth noting that the news about L'Aquila's severe earthquake of 2009 was first announced through Twitter before other media (Prof. Cristina Capineri, 2014, pers. comm., 3 June).

3.6.3. Crowdsourcing satellite imagery in Somalia.

This is a humanitarian project to geo-locate all shelters in Somalia's Afgooye corridor with the aid of satellite imagery provided by the Standby Volunteer Task Force. UNHCR, DigitalGlobe, Tomnod, SBTF and Ushahidi are the main organizational bodies cooperating so that the crowdsourcing application can take place with the aid of volunteers (iRevolution, 2011a). The aim of the project behind this collaboration is to map all shelters by dividing them into three main categories: large permanent structures, temporary structures with a metal roof and temporary shelters without a metal roof. The rule set describes the shape, color, tone and clustering of the different shelter types. The project was divided into two phases: a trial and an official launch where specific instructions were given to participants. The goal of the project is to test the feasibility of crowdsourcing rapid shelter enumerations of internally displaced persons to support population estimates. The process cannot be replaced by an automated one as this could not identify the type of shelter.

The satellite imagery methodology was adopted because access to the area of interest is limited. The main question was how many people are in the shelters and need humanitarian aid in order to inform decision making around logistics and planning policies. During the project, 253,711 tags were created and more than 9,400 shelters visually identified after processing 3,909 satellite images (iRevolution, 2011b).

3.7. Technical aspects

The research above indicated great potential in terms of technical aspects. Innovative ideas, flexible and out-of-the-box techniques and tools are only a few of the main components revealed by the case studies.

Combination of conventional and open source data. Many crowdsourcing projects use a wide range of software applications, both closed and open source. The successful case studies have proven that combining various tools in different applications can widen the technical horizons of an application and create new opportunities. One of the most predominant examples is the Mapping in Nairobi, Kenya (Map Kibera, 2014). However, access to the knowledge and experience of using these software tools is not available to everyone and requires high technical abilities.

Data sets. Another issue with VGI data sets is the need for synchronization and coordination. During update operations, data sets often diverge but the users and recipients of a project should know which version is the correct one and how to maintain a definitive copy. In some cases, and especially where open source software is used, the format of data is not convenient for further use in proprietary software packages, making it difficult to reintegrate the data. Therefore, the interoperability of data formats is a significant issue.

Accuracy and quality. The accuracy of the information continues to play a key role in VGI projects. Community Mapping for Exposure in Indonesia indicated that accuracy varies among the different data sets, which is an issue of concern. Elsewhere, the Colorado pilot project for the National Map Corps showed that accuracy significantly improved when volunteer participation increased. A related concern includes the accuracy of data collected by mobile phones, as in the iCitizen project where this is the main issue. However, there are many methods for quality assurance of VGI and these can be used to ensure the accuracy and quality of the information.

Authority. The authority given to VGI data is one of the most challenging issues for its use in government. In a departure from an era in which information is considered authoritative simply because it originates from a government organization, recognition of the inherent heterogeneity in geographical information and the need to keep it up to date permeate many of the case studies. However, because government bodies have both the authority and the responsibility to provide accurate and comprehensive information, this requires more control over the data and its quality. Many of the case studies show that governmental organizations need to put appropriate procedures in place to ensure that, regardless of the source, the information released is accepted as trustworthy and valuable.

3.8. Success factors

According to the research, elements that contribute to the success of VGI projects should be considered from the outset and are often linked to the original drivers.

Identification of appropriate cooperation level between the public and governments. Approval and acceptance by the government is central to VGI success in this context, regardless of the stage of the project. Approval means not only the simple adoption of crowdsourcing techniques but also the cooperation between the public and government in a continuous effort to produce the desired result. Governmental experimentation plays a crucial role in identifying how to incorporate crowdsourcing techniques into official activities and projects. VGI support is divided into two main categories, that offered during the evolution of the project (e.g. NRCan-OSM ongoing collaboration) and that offered in its aftermath (e.g. South Sudan government's evaluation of the project by Google Map Maker and the Sudanese diaspora). In contrast, it is notable that the outcomes of the Haiti disaster response were not subsequently used by the local official mapping agency, though they were used by other humanitarian actors operating in the country at the time. This represents a missed opportunity to establish a richer connection between the Haitian government and the OSM community.

Partnership of scientific organizations. Strong collaboration between different organizations, which are experts in different parts of a project, is key to success. Although in a few cases this has lead to a lack of coordination and duplication of data (e.g. the Haiti disaster response), in others duties are separated into technical, economic and human resources (e.g. the National Map Corps project). Research organizations and universities can play a positive role in this as centers of innovative ideas and techniques as well as participants and volunteers.

Workshops. A series of workshops carried out in the preliminary stages of projects encourages the training of volunteers and defines the pattern in which participants will coordinate. It is noticeable that among the most successful stories (e.g. Community Mapping for Exposure in Indonesia, Map Kibera in Kenya, and mapping of South Sudan) the workshops indicated the value of partnering with scientific organizations such as local universities to train volunteers and conduct quality assessment to ensure government acceptance of the data.

Recruitment of volunteers. Although the common view is that the public can participate without restriction in all crowdsourcing applications, the reality is quite different. Most projects are oriented to specific tasks and recruit the public according to their age, background or technical skills. One example is Community Mapping for Exposure in Indonesia (Humanitarian OpenStreetMap Team Indonesia, 2013), where young undergraduate students were recruited and scholarships offered in exchange for participation. As crowdsourcing reaches new locations, compensations and awards to participants may also become more important, as in the case of Map Kibera (Map Kibera, 2014).

Innovative techniques. In an effort to keep the interest of the public and adopt new technologies and platforms, different organizations have promoted new crowdsourcing techniques, such as gamification and reporting with the aid of photographs, video and SMS (e.g. Map Kibera) or use of social media (e.g. Twitter use in Italy).

3.9. Concluding Remarks

This chapter investigated ten successful crowdsourced case studies that covered a wide field of applications and which flourished with the aid of governmental or official partners. All case studies faced the challenge of gaining acceptance and support from governmental bodies, which can be considered as their main victory towards changing traditional practices. Among the successful factors, the identification of the appropriate cooperation level between the public and governments is firmly underlined as an important note for further case studies.

The research separated all those key factors found to be important for the success of potential VGI applications. The study also demonstrated the technical factors and the successful components that emerged from the conclusion of the practical experiments.

The research indicated that a combination of conventional and open-source data, the credibility of the data sets, their quality and authority constitute the most important technical factors that should be taken into consideration in the design of future projects. Also, the involvement of different organizations, the recruitment of volunteers and the adoption of innovative techniques are only a few of the successful aspects that may be used in any general crowdsourced application.

The table below summarizes the main results of the third chapter.

➢ Ten different successful case studies were explored in depth. All had in common the acceptance and support of the official partners, who realized the importance and significance of volunteers in the implementation of every experiment. Every case study was analyzed and its main lessons were summarized for further evaluation and use.
➢ Among the most important technical aspects noted are the combination of conventional and open-source data, the credibility of the data sets, their quality and authority.
➢ The predominant success factors include partnership of different organizations, recruitment of volunteers, implementation of workshops at the beginning of every application and innovative techniques.
➢ The crowdsourced case studies show these projects can flourish and be maintained, especially if they gain support from governments and receive acceptance from official partners.

Table 3-10: Concluding remarks of the third chapter

4. PROPOSED CROWDSOURCING MODEL FOR CADASTRAL SURVEYS

4.1. Introduction

The fourth chapter investigates the core part of the research and proposes a crowdsourcing model based on the theoretical study, previous examples and innovative techniques. Although the model focuses on cadastral surveys, it is presented in a more general pattern so that it can be adopted and used in various land administration projects. Its main innovation is the adoption of various elements and keynotes derived from a range of case studies that all share principal success factors known from the outset. The research aims to propose general principles as guideline in future land administrative projects and crowdsourcing initiatives.

The chapter begins by investigating how the Hellenic Cadastre has been designed and how it works. The study presents its main stages, its process and the failures that it has suffered in recent years. The Hellenic Cadastre project is used as a guideline in the general model that will be presented in the second half of the chapter.

The study subsequently proposes an alternative crowdsourced model for cadastral surveys that could potentially replace official processes and is based on the main lessons that have been derived from the study of ten different practical experiments. In fact, the chapter is divided into two main sub-chapters. The first sub-chapter is focused on the HC project and its practices. The research presents the legal framework, official process and deficiencies that have been recorded within the first phase of the cadastral survey in various areas. Within the next sub-chapter, the proposed alternative cadastral model is presented. The model has been designed according to those components that were evaluated as crucial for the success of a general model in the previous chapter and were modified so that they fit the purpose of a cadastral survey.

The main innovation of the research is focused on the idea to isolate all key factors and modify them so that they can be introduced into the potential cadastral project or any other land administrative project that also faces difficulties or restrictions. The analysis is enhanced with the success factors that play a fundamental role in each case study. The main lessons, capacities and weaknesses lead to this next part, which investigates the proposed crowdsourcing cadastral model. The model is clarified in terms of its technical and sociological aspects while describing the proposed process. The workflow, stakeholders, adopted main lessons from previous experience and coordination with the INSPIRE directive are the main four basic components of the proposed cadastral model. The chapter ends by illustrating the main findings.

The table 4.1 indicates the main components of the fourth chapter.

➢ Presentation of the HC as an administration project that can be used as a guideline for the design of the proposed crowdsourcing project.
➢ The Hellenic Cadastre: how it works, its progress and its deficiencies.

➢ The alternative crowdsourced model for cadastral surveys. The idea behind its implementation and general application in a variety of projects.
➢ List of the keynotes that were derived from previous experience.
➢ The workflow and stakeholders as the main components of its design.
➢ Potential coordination with the INSPIRE directive as a major aim for its credibility and viability.

Table 4-1: Predominant components of the fourth chapter

4.2. The Hellenic Cadastre

Greece is located in southern Europe, at the crossroads of Europe, Asia, and Africa. Its land boundary is 1,160 km and according to the 2011 census, its population is around 11 million inhabitants. Greece consists of a mountainous, peninsular mainland jutting out into the sea at the southern end of the Balkans, ending at the Peloponnese peninsula, and features a vast number of islands. "The land is highly fragmented and due to the strong urbanization of the last 50 years, most of the population is concentrated in few big cities and great extents of rural and mountainous areas have been abandoned" (Rokos, 2009).

The implementation of the Hellenic Cadastre is a long-term project of significant importance for the development of the country and Greece is one of the very few European countries where a cadastre does not exist (Ioannidis & Hatzichristos, 2000).

The Hellenic Cadastre is a uniform, public, systematic and on-going title registration information system in fully digital form with spatial and attribute records of each land parcel, under the responsibility and guarantee of the National Mapping Agency (NCMA S.A.). The HC is responsible for both the collection of all necessary spatial information concerning land parcels and the registration of all legal rights on them as attribute documentation.

The main properties of the Hellenic Cadastre (Arvanitis & Koukopoulou, 1999) are:

- Uniformity: the Cadastre is compiled and updated based on unique standards for the whole of the country.
- Public character: the state has responsibility for the compilation of the Cadastre and it will guarantee the contents of cadastral books and maps.
- Update: all the transactions are registered into the system at the time they occur.
- The cadastral unit is the land parcel as it is described in the legal documents.
- The geometric description of the land parcels is achieved through the cadastral maps, which are based on a unified Geodetic Reference System.
- The various land rights are registered in cadastral tables and finally in cadastral books.
- The cadastral identification number (land parcel identifier) is used in order to connect different kinds of information.

Potsiou *et al.* (2000) conducted a brief historical review of the continuous efforts of the Hellenic state to introduce a cadastral system since its establishment in 1825. The Greek state became the owner of the largest part of the country as the successor of the Ottoman

Empire. However this information was never registered in a systematic and uniform manner (Rokos, 2009). More than ten individual efforts to implement a cadastre in Greece have been launched since 1836, however three among them are still in operation. In the year 1853, the French Mortgage Bureaux System, a deeds registration system, was introduced. This system, named the Transfers and Mortgages Registration System, is still valid in Greece.

Moreover, between 1926 and 1929 a cadastral system was established on the islands of Rhodes and Kos in Southern Greece, known as the Dodecanesean Cadastre. The system continues to operate today, according to a special Cadastral Regulation.

The Hellenic Cadastre, which was first introduced in 1995, is designed to be a modern information system, which will improve the efficiency of land transactions and guarantee land tenure. In addition it will provide all levels of information to both private and public sectors, which is necessary for land management, urban and rural planning, agricultural policy, land administration and above all environmental monitoring (National Research Council, 1980, Economic Commission of Europe, 1996).

The operating system of the Transfers and Mortgages Bureau is a "person-centric" system, where deeds are registered together with all legal rights concerning the real estate (Ioannidis & Hatzichristos, 2000). The system constitutes an attribute data record but all spatial data is missing. Among other weaknesses, the system:

- stores only individual topographic diagrams that may have been submitted with the contracts by the notaries. The submission of a diagram to the Bureau is not compulsory and the accuracy varies depending on the different parameters. The result tends not to be exploitable for re-use.
- is not digitized. The contracts and the diagrams are stored in a hard copy format and research is therefore difficult.
- is "person-centric" and organized by Bureau unit. Research by a land parcel is impossible.
- is not updated as it is based on voluntary records.

The project of the Hellenic Cadastre will be a "land parcel-centric" digital GI system and it will cover the whole jurisdiction of Greece and address the existing lack of spatial data.

The main model is constituted by four sub-systems: properties, property rights, beneficiaries and deeds. Kavadas (2012) states that every part of land at the municipal level (including roads, streams, special areas, etc.) constitute cadastral parcels. Also, the spatial information is fully connected with legal and property information and is created by using the Hellenic Positioning System (HEPOS) in field measurements. A recent full-coverage network of reference points has been created to support the spatial data collection. Part of the project is outsourced to external contractors and any detected errors or non-conformities in the data are corrected by the contractors.

According to his study, the general conceptual model of the Greek Cadastre is depicted in Figure 4.1:

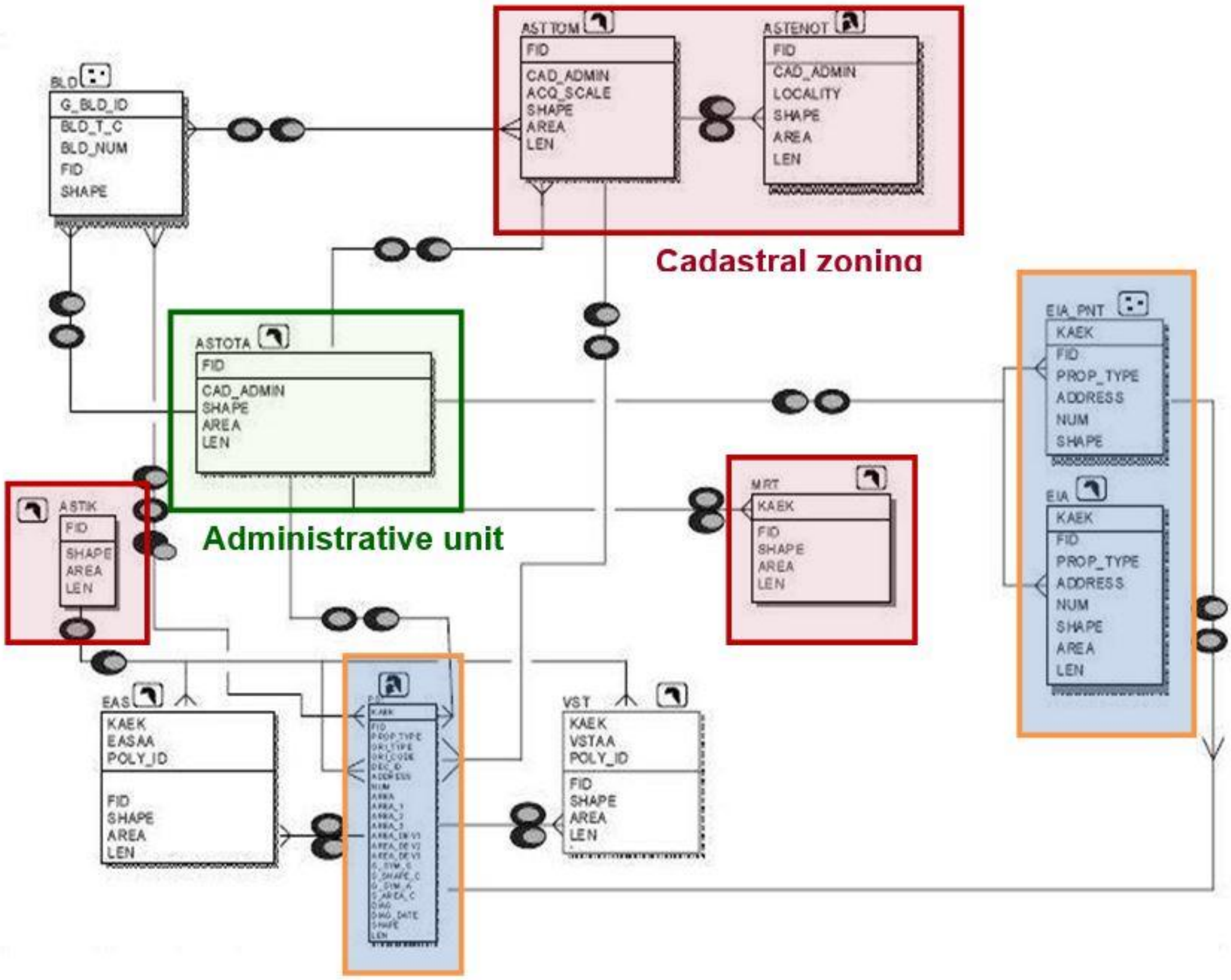


Figure 4-1: General conceptual model of Greek Cadaste (source: Kavadas, 2012)

4.2.1. Legal framework of the Hellenic Cadastre

The basic legislation for the compilation of the Hellenic Cadastre is constituted by a series of laws with their amendments. The 24th Article of the Constitution of the State establishes the obligation for the compilation of the National Cadastre by the state.

The Law 2308/1995 (Government Gazette A', 114/15-06-1995) rules for cadastral surveys for data collection and describes the adjudication procedure. The Law 2664/1998 (Government Gazette A', 275/03-12-1998) describes the fundamental principles of the operation of the Cadastre, describes the regulations under which the first registrations are made, defines the content of the cadastral record and the responsibility for the operation/maintenance of the cadastral data (Potsiou *et al.*, 2000).

The laws that have amended the two principal laws are the following: 2508/1997 (Government Gazette A', 124/13-06-1997), 3127/2003 (Government Gazette A', 67/19-03-2003), 3208/2003 (Government Gazette A', 303/24-12-2003), 3212/2003 (Government Gazette A', 308/31-12-2003), 3481/2006 (Government Gazette A', 162/02-08-2006), 3559/2007 (Government Gazette A', 102/14-05-2007) and 3728/2008 (Government Gazette A', 258/18-12-2008) (Koukoutsi, 2010).

4.2.2. Cadastral survey practices in Greece: official process, progress and statistics

The HC Project started in 1995 and cadastral surveys have been carried out in 340 regions all over the country while 106 cadastral offices have already begun operations in these regions. The responsible agency for the HC project is the National Cadastre & Mapping Agency S.A. (NCMA S.A.). The whole process is divided into two phases. The first one started in 1995 and ended in 2008. As of June 17th 2008, the second phase of cadastral surveys is in progress in 107 municipalities, communities and local districts in Attica, Thessaloniki and the capitals of prefectures that were not surveyed along the lines of previous surveys (Rokos, 2009). It is estimated that from June to December 2008, more than 2.8 million people declared about 5.1 million real property rights to the Cadastre. In the same period 17,000 legal entities declared another 700,000 ownership rights (Hellenic Cadastre, 2011a). The compilation process is focused on collecting, editing and recording property and other property rights per property unit offering the opportunity for an accurate, authoritative and assured (AAA) cadastre (Williamson, 2012).

The spatial cadastral data are derived from (Kavadas 2012):

- the cadastral survey process (field surveys).
- the digitization of the obvious materialized parcel boundaries on orthophotos.
- the spatial cadastral data that accompany the deeds after adjustment to the geodetic reference system of the National Cadastre.
- the boundaries of coastal and forest areas.
- the verification and use of the data submitted by the owners together with the declarations (e.g. topographic diagrams).
- the spatial data derived from property titles (area, length of parcel sides, etc.).

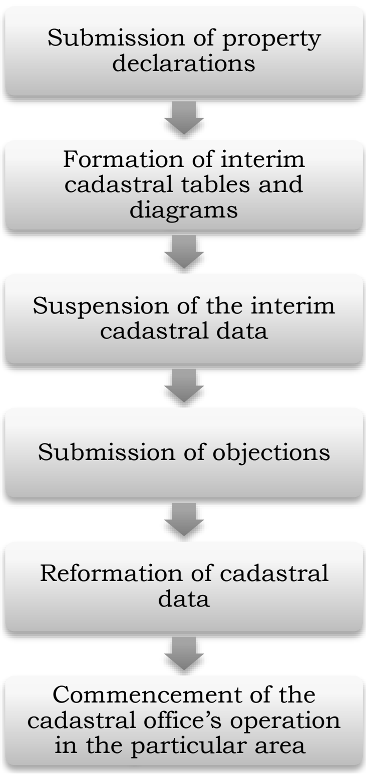


Figure 4-2: Main cadastral stages

- the participation of the owners in the indication of boundaries on orthophotos by visiting the contractor's office.

The time needed for the official process to be completed is not standard at all stages of the process and the time for the process to begin may vary depending on disputes among the various candidate contractors. The time required for the process to begin may reach three years or may lead to a cancellation of the public tender. Numerous areas of the country suffered severe delays and postponements from 2008 until 2013 for this reason. The main cadastral survey includes the following stages [Figure 4.2]:

- Declarations are submitted to the cadastral survey offices by the right holders and the registration of the declared rights is added to a digital database. The declaration period is intended to last for three months for landowners except for those who live abroad and can declare their ownership in a six-month period. However, due to the high levels of citizen participation, most of the declaration periods are extended and finally reach six months in total [Figure 4.3].

- Interim cadastral tables and diagrams are formed based on the data from the submitted declarations, which has been processed by lawyers and surveyors.

- Interim cadastral maps and data are published for a two-month period and extracts are sent to the rights holders for their information and acceptance. This period may also be extended, if needed.

- Objections or applications for correction of a cadastral registration are submitted and forwarded to independent administrative committees, depending on the case. Objections last two months and the period is overlapped to the above. In case severe errors are recorded, the process follows as it is given in the next sub-chapter. The time required is set at three months only for straightforward situations and its real duration varies depending on the severity of the errors and the number of extensions that need to be granted by the official authority. The experience, below, indicates that the time needed is not standardized.

- The cadastral data is reformed after examination of the objections and the correction claims and the final cadastral tables and diagrams are formed. These registrations are called Initial Registrations and they constitute the first registration in the Hellenic Cadastre.

- The cadastral office in operation in the particular area replaces the old Land Registry Office (Hellenic Cadastre, 2011b).

Figure 4-3: The hard copy declarations that the owners submit to the cadastral offices (source: NCMA S.A.)

Although the project has been in progress for 20 years, the results are quite disappointing concerning its process and its efficiency. The project involves an area of 132,000 km^2 and 37,200,000 property rights approximately. However, by 2012 only 6.4% of the total area has been completed which means that 8,400 km^2 and 6,800,000 property rights (17%) have been officially recorded. Progress remains slow. The total cost of the project has reached 340 M €. Currently, approximately 3,100 km^2 of the total area and 7,500,000 property rights are under compilation. The cost of the cadastral survey is estimated to be 212 M € - not including VAT – and the registration of rights costs 42 M €. The remaining 120,500 km^2 and 22,900,000 rights concerning mainly rural areas are still unregistered and the total cost of the project has not been defined (Potsiou & Basiouka, 2012). Arvanitis & Koukopoulou (1999) characterized the HC project as being of a huge size and budget, and predicted that it would take more than 15 years to be fully completed. The progress of the project has refuted them.

4.2.3. Technical specifications of the mapping agency

The most recent technical specifications for cadastral surveys are declared in the 49439/16-9-2013 decision of the Minister of Environment, Energy and Climate Change and were published in the Official Government Gazette B', 2362/23-09-2013. The publication of the technical specifications poses a series of explanations and rules according to the experience gained over previous cadastral surveys and the structure of the Operative Cadastre.

The Hellenic Geodetic Reference System 1987 is used as a reference system with ellipsoid GRS 80 and semi-major axis a=6378137.000 and flattening 1/f = 298.257222101.

The WGS 84 is in parallel to the HGRS 87 and the transformation between the two systems is applied by the parameters $\Delta X = -200$ m, $\Delta \Psi = +74$ m $\Delta Z = +246$ m. The known parameters for the transformation of the two systems is of vital importance for crowdsourcing techniques based on GPS tracks that collect coordinates in WGS 84.

The true color, digital, long-scale orthophotos of 50 cm spatial analysis provided by the official mapping agency work supplementary to the cadastral surveys and have geometric accuracy RMSEx ≤1.00 m, RMSEy ≤ 1.00 m, RMSExy ≤ 1.41 m, and absolute accuracy ≤2.44 m for 95% reliability. The LSO cover the areas that are under cadastral compilation in total.

The true color VLS orthophotos of 20 cm spatial analysis basically cover the urban areas. They are fully rectified images including land and technical constructions. Their geometric accuracy for points on the earth is RMSEx ≤0.20 m, RMSEy ≤ 0.20 m, RMSExy ≤ 0.28 m, and absolute accuracy ≤0.48 m for 95% reliability. Their geometric accuracy for points on the constructions' roofs is RMSEx ≤0.40 m, RMSEy ≤ 0.40 m, RMSExy ≤ 0.56 m, and absolute accuracy ≤0.97 m for 95% reliability.

The geometric accuracy of the cadastral diagrams is checked by comparing a number of points of delineated boundaries, whose coordinates are well known in advance or have been measured with high accuracy in the field, with the same points as they are presented on the cadastral diagrams. The geometric accuracy is RMSEx ≤0.40 m, RMSEy ≤ 0.40 m, RMSExy ≤ 0.56 m and the absolute accuracy is ≤0.98 m for 95% reliability in urban areas. The corresponding geometric accuracy is RMSEx ≤1.00 m, RMSEy ≤ 1.00 m, RMSExy ≤ 1.41 m, and absolute accuracy ≤2.45 m for 95% reliability in rural areas.

The technical control ends when every land parcel is located in the correct cadastral unit and its shape and size is similar according to the topographic diagram, which has previously submitted by the landowners and the respective rights. The shape of each land parcel is checked by a buffer zone of compatibility. Compatibility of shape exists when the buffer zone, which is located between the internal and the external boundaries of a land parcel, does not exceed 0.50 m in urban areas and 2.00 m in rural areas.

The compatibility of area size is checked by applying the equation $\Delta_E = |E - E_\Delta|$ where E is the measured area for cadastral purposes and the E_Δ has been declared by the landowner according to his rights and topographic diagrams. The result should be lower or equivalent to the permitted deviation so that the deviation can be approved.

4.2.4. Identified errors – four representative examples

Within the implementation of the project, and especially taking into consideration its magnitude, specific deficiencies have been recorded in the cadastral surveys. Identified errors concerning the location, the shape and the boundaries of land parcels have been recorded in various areas where cadastral survey has been completed. Errors are also noticed in the records of the cadastral tables where properties are recorded to belong to "unknown owners". Among the most important are those at Lefkada island, Corfu, Lesvos, Chios, Alonissos, Kefalonia and Zakinthos island. It should be noted that the declaration only concerns geometrical divergence of property, not property rights.

More precisely, there are four district categories of errors that affected the areas mentioned above:

- Land parcels whose shape or boundaries need correction.
- Land parcels, which although they were declared by the owners within the deadline of the declaration period, were not recorded by the contractor in the interim cadastral plans so were not recorded at all.
- Land parcels which were registered on the interim cadastral plans as belonging to the wrong cadastral units.

Figure 4-4: The areas that suffer multiple failures within the official cadastral process.

- Land parcels which are located in adjacent cadastral units and are affected geometrically due to the correction of the boundaries of the unit under re-survey.

According to Papadopoulou (2012), the majority of errors were recorded in areas with common characteristics such as rural areas with no materialized boundaries on the field, in areas that are abandoned by their habitants or areas that suffer of high percentages of immigrants. The Law 2664/1998 (Government Gazette Gazette A', 275/3-12-1998) that describes the fundamental principles for the operation of the Cadastre also describes how the spatial data can be improved within the Article 18.1 and 19.2. However, the implementation of the Cadastre indicated that additions are required within this law. The law was improved by inserting the 19.1 article where it is stated that the cadastral survey can be repeated in cases that a generalized adjustment of the boundaries or location is noticed. According to data derived from the responsible agency, the research has identified the islands that faced the most severe delays within the cadastral procedure. The main affected areas are given below [Figure 4.4].

Alonissos island

Alonissos is one of the islands that suffered multiple errors within the cadastral process and in which geometrical divergence of land parcels within cadastral charts has been reported since the launch of the cadastre operation. The property redefinition process, a governmental initiative, was implemented by the national mapping agency, with the contribution of the municipality of Alonissos and the participation of landowners. Figure 4.5 indicates the area of interest, with the initial boundaries in red and the corrected boundaries in blue.

The process followed to correct the errors is divided into field surveys and follow-up work at the office. At first, an interim drawing was designed for every ownership and its boundaries were marked with the aid of the landowners who were responsible for the recording and were obliged to approve it by signing it. Secondly, research was carried out in the archive of the cadastral office where record and data correlation was undertaken by surveyors and lawyers. The elaboration of the data was carried out by taking into consideration the interim cadastral declarations, the contracts, the objections, the decisions of the competent committees and the topographic surveys that were carried out by surveyors, which were outsourced by the landowners to help with the process.

The property redefinition process began in April 2012 and was first designed to last three months. However, numerous extensions meant it ended only on 30th November 2012 and lasted nine months in total. It is notable that Mr Bekos, executive member of the NCMA S.A., underlined in a press conference given at Alonissos island that citizen participation was an important prerequisite for the successful completion of the process.

The results ended in 71 unique ownerships and 10 unknown landowners while 66% of the initial ownerships were corrected in shape or boundaries and 14% were corrected in position as they were previously registered in the wrong cadastral units.

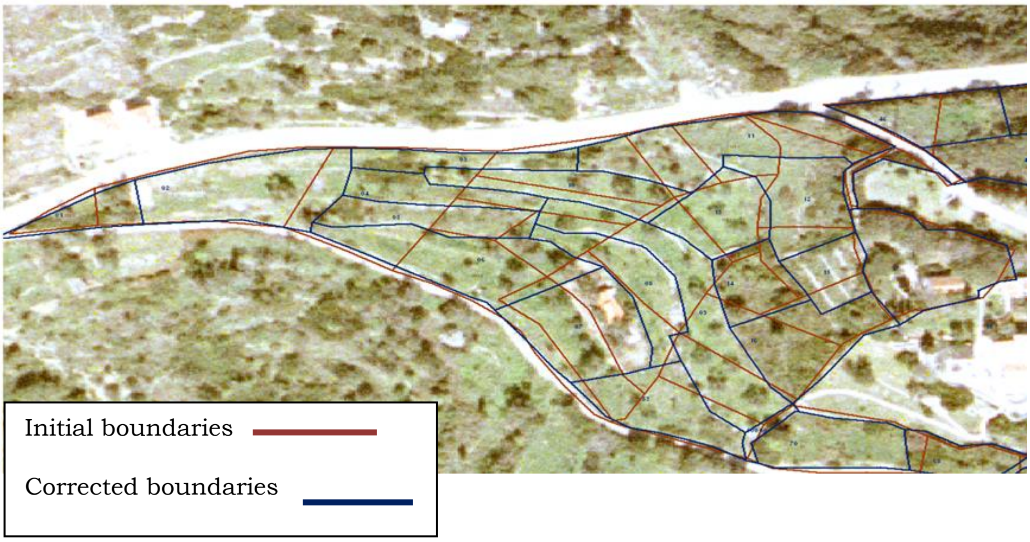


Figure 4-5: The corrections in a cadastral unit on Alonissos Island (source: Papadopoulou, 2012)

Chios island

Chios faces similar cadastral issues and the cadastral process has been repeated by following exactly the same official procedure as on Alonissos island. 113,400 land parcels were recorded and more than 34,020 errors have been detected on the island. The policy is the same and the corrections are given in the map below. The results indicated that 76% of ownerships had to be corrected in shape or boundaries and 23% were corrected in position as they were previously registered in the wrong cadastral units (Papadopoulou, 2010) [Figure 4.6]. The property redefinition process began in February 2012, and was first applied for a three-month period as on Alonissos island. After three extensions, the process ended on 31st August 2012. The process lasted six months in total.

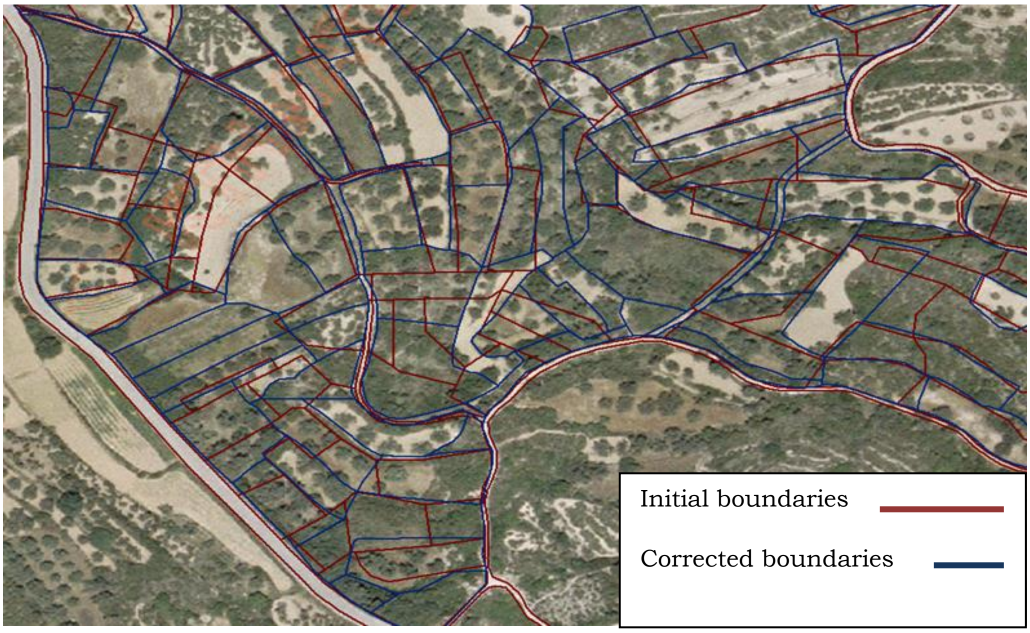


Figure 4-6: The corrections in a cadastral unit in Chios Island (source: Papadopoulou, 2012)

Lefkada island

Lefkada was affected mainly in two different cadastral areas [Figure 4.7.]: Tsoukalades and Haniotes villages. It is estimated that in Tsoukalades village 43,440 land parcels were recorded in total while 790 errors have been found to date (Papadopoulou, 2010).

In this neighborhood the official process was repeated and a new cadastral survey was also carried out with owners' participation. The results in Lefkada island meant that 80% of ownerships were corrected in shape or boundaries and 20% were corrected in position as they were previously registered in the wrong cadastral units. More precise explanation is given in the seventh chapter of this study.

A one-month deadline was given in Lefkada island at first so that the property redefinition process could be implemented in February 2012. After the local authority's intervention, the period extended for four months and ended on 31st July 2012.

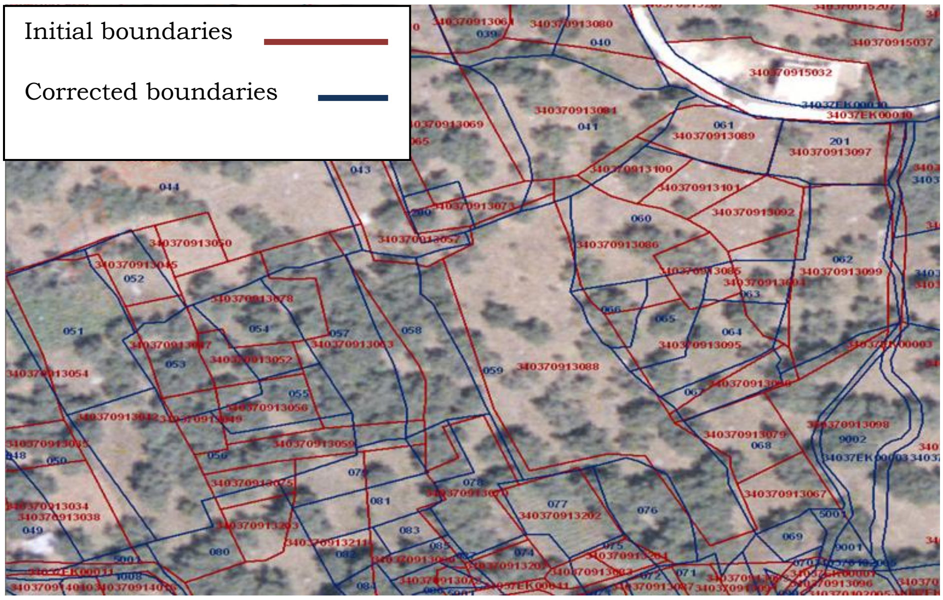


Figure 4-7: The corrections in a cadastral unit on Lefkada island (source: Papadopoulou, 2012)

Lesvos island

Lesvos is also among the areas where gross errors have been recorded during the objection period. More than 2,500 objections were submitted in the period that 42,205 land parcels were registered. It is estimated that the percentage reaches 30% (more than 12,000 land parcels) and the cadastral survey was repeated in coordination with Lesvos municipality (Papadopoulou, 2010).

The property redefinition process began in December 2011 and was first applied for a three-month period as on Alonissos and Chios islands. According to the official announcements published by the mapping agency, it is not clear when the process officially ended. However, the last extension was given in August 2012.

4.3. Proposed model for cadastral surveys

The proposed crowdsourced model for cadastral surveys (Basiouka & Potsiou, 2015) is the result of the main lessons that have been collected from a series of successful governmental crowdsourced projects that were analyzed in depth (Haklay *et al.*, 2014); the requirements posed by the nature of a cadastral project; the innovative ideas the researcher has decided to introduce; and the necessity for coordination with formal cadastral procedures and realities [Figure 4.8]. As previous research carried out by Haklay *et al.* (2014) indicated, the key factors for a successful crowdsourcing experiment include building on previous experience, leveraging existing technology and having the support of key partners such as governments or other authorities. The proposed model aims to take advantage of previous experience of official procedures and to introduce innovative techniques that will facilitate them.

The structure of the proposed model is divided into three main sections: the adopted main lessons identified from the successful case studies, which will be incorporated in various parts of the model: the proposed workflow, which will replace the official procedure; and finally the participants and stakeholders of the project. The aim of the research is to launch a model that may be applied and used either at a local or a national level; and it may have a wider application in many countries and communities that face land issues.

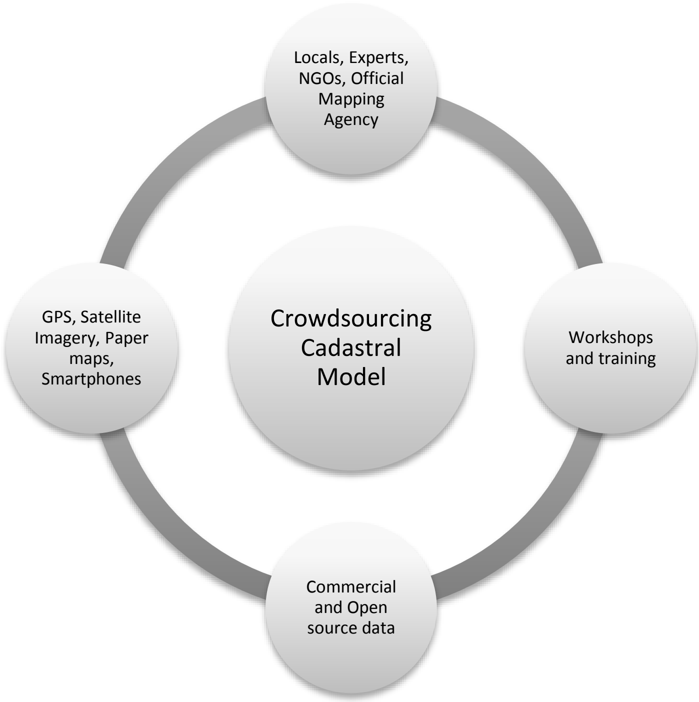


Figure 4-8: The proposed crowdsourcing cadastral model

4.3.1. The main lessons adopted

Within the specific alternative proposed model for cadastral surveys, a series of main lessons, technical aspects and successful factors are adopted as vital for the viability of the model. The majority of them serve the nature of the research and play a crucial role in its design. The predominant key factors are given below and are explained in terms of the proposed cadastral model.

➢ ***Training and workshops*** should take place at the beginning of each application. Most of the practical applications that constitute successful crowdsourced paradigms – such as Community Mapping for Exposure in Indonesia, MapKibera in Kenya and mapping of South Sudan – introduced workshops as a key factor for their success. This is of vital importance due to the technical requirements of a cadastral survey and the quality controls that should be satisfied at the end of any project. The workshops have three different targets: (a) to inform locals about the necessity and benefits of the project, (b) to recruit them and (c) to train them to properly manipulate spatial and attribute data.

➢ ***Recruitment of volunteers.*** Except for local people – landowners who will play a vital role in data collection – the proposed model is based on non-governmental organizations and undergraduate students of the schools of SRSE, Geography or any other relevant field. Both will keep the cost low and the students will support the cadastral surveys both practically and technically. The undergraduate students will participate actively in the data collection and editing. The idea for this came accidentally due to the nature of the study, however, Community Mapping for Exposure in Indonesia had already recruited undergraduate students to collect a huge amount of data in a relatively short time and scholarships were offered in exchange. The idea behind the recruitment of non-governmental organizations is to carry out all workshops at the beginning of the process. Students should also deal with the great amount of data that should be collected and manipulated. The main question over the participation of landowners as volunteers is in terms of their motivations. Landowners may be more easily recruited if cadastral fees were eliminated, or similar taxation rates lowered, as a result of their participation. Experience from other countries has indicated that the incentives that lead volunteers to participate in crowdsourcing projects are a mixture of various parameters. The landowners will participate voluntarily for altruistic reasons if they recognize the necessity of the project, how their lives will be affected by its implementation and how their properties will be protected. This is especially the case for those who face difficulties in land transactions, use and development. However, the majority will be motivated if a compensation rate is offered to them.

- ***Partnership of scientific organizations.*** Collaboration between the various organizations is proposed within a well-defined and compact pattern where the roles and duties are made clear from the beginning of the procedure. To avoid the lack of coordination and duplication of data noted in Haiti disaster response, each stakeholder should be responsible for a specific part of the cadastral survey and all the participants should work in cooperation in order to produce the final result. Supervision and quality controls should also be carried out by experts. The main innovation of the project, which has a national application, is based on the participation of various NGOs at local level. The NGOs that take action at local level should be responsible and should participate actively in the cadastral surveys in these areas.

- ***Crowdsourcing projects may also be coordinated and implemented from a distance***. The importance of this keynote is crucial for the success of the first phase of the cadastral survey where citizens should digitally declare their ownership from a distance instead of hard copy declarations and indicating their ownership on digital orthophotos at the cadastral offices. The phase may be carried out in digital form and implemented from a distance. The attribute data declaration may be replaced by an online declaration with the aid of Apps or online tools and the field work for spatial data collection in urban areas can be replaced by the online digitization of land parcels on orthophotos provided by the website of the official mapping agency or on OSM. This specific strategy worked efficiently in the mapping of South Sudan.

- ***Open-source and conventional software*** should be used because experience has indicated that their combination offers the required freedom and openness for the project. The informal settlement mapping in Nairobi, Kenya, flourished with the aid of open-source and conventional software. Open-source software may be used in data collection while conventional software may be used in data manipulation. The contribution of volunteers in data collection requires the use of flexible and easy-to-use tools. The editing of data demands advanced functionalities that may be available only in conventional GIS software packages. Previous experience has indicated that using a range of software, programming languages and platforms may broaden a project's horizons.

- ***Innovative techniques.*** In an effort to meet the requirements of the project, especially in terms of quality, a series of innovative techniques have been adopted in data collection and manipulation. For the first time, OSM is tested for use in data manipulation and storage in cadastral surveys. Also, smartphones and handheld GPS gradually replace the expensive equipment that is needed for data collection. All these innovations were introduced to propose an alternative, viable solution to the official procedure.

4.3.2. The workflow

The workflow of the proposed model follows a general pattern that includes all different occasions of mapping in rural or urban areas, and it constitutes of four main steps. The proposed model may be applied at the beginning of a cadastral survey and it may replace the first phase of official cadastral mapping. The hard copy declaration of ownership, the identification on orthophotos of properties in the rural areas and the acceptance of the produced result are only a few stages of the official process that may be modified. Although the procedure may be categorized in these four stages, it may include further parameters that are identified within the practical experiments [Figure 4.9].

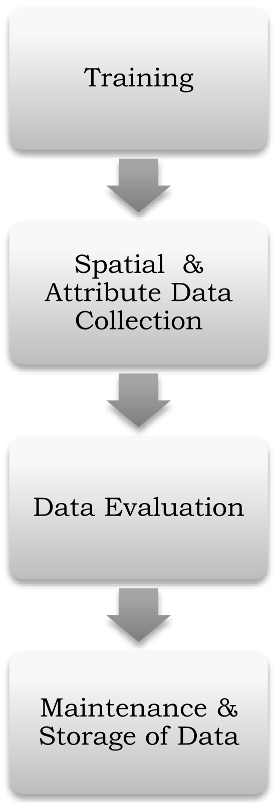


Figure 4-9: The proposed workflow

Training of volunteers is the first step of the process. The NGOs and the undergraduate students will train the landowners both theoretically and practically. The award for the participation of students will be in the form of scholarships and work experience.

Data collection as the second step of the workflow differs depending on the nature of the area and the kind of data that should be collected. Rural areas require a different approach in comparison to urban ones while spatial data collection requires different tools to attribute data.

The spatial collection of parcel boundaries may be done by using three different methodologies. The first approach is focused on the plain declaration of ownership by giving the point of its centroid [figure 4.10, right]. The benefits are obvious: a quick and inexpensive method, which may be implemented only with the participation of citizens. The volunteers may take a single measurement and can declare their ownership online. However the boundaries are not obvious and the center may vary in complex shapes. This process fits in areas where official cadastral declaration is at a preliminary stage.

The second approach is focused on collecting parcel boundaries with the aid of a handheld GPS, tablet or smartphone [figure 4.10, left]. Although the approach is quite vulnerable in terms of quality, it may be used for the creation of interim cadastral maps. The volunteers collect spatial data with expert support after been trained. Thus, society is put at the center of decision making policies, which is vital for the success of projects that affect the life of citizens.

The third approach follows the online approach. Citizens can declare their ownership by using online dynamic maps and/or online orthophotos as basemaps which are provided via the website of the official mapping agency. Experience has indicated that this specific methodology is extremely successful in areas where boundaries are shown on the orthophotos.

The correlation between the OSM and the Cadastre as an easy and quick idea for the creation of interim cadastral maps is advised in case of a lack of other accurate basemaps in urban areas. The restrictions that the official mapping agencies adopt in measuring prohibit the use of handheld GPS devices. Although in urban areas there are high-resolution satellite images, the majority of mapping agencies ask for field measurements, which are not only expensive but also time consuming.

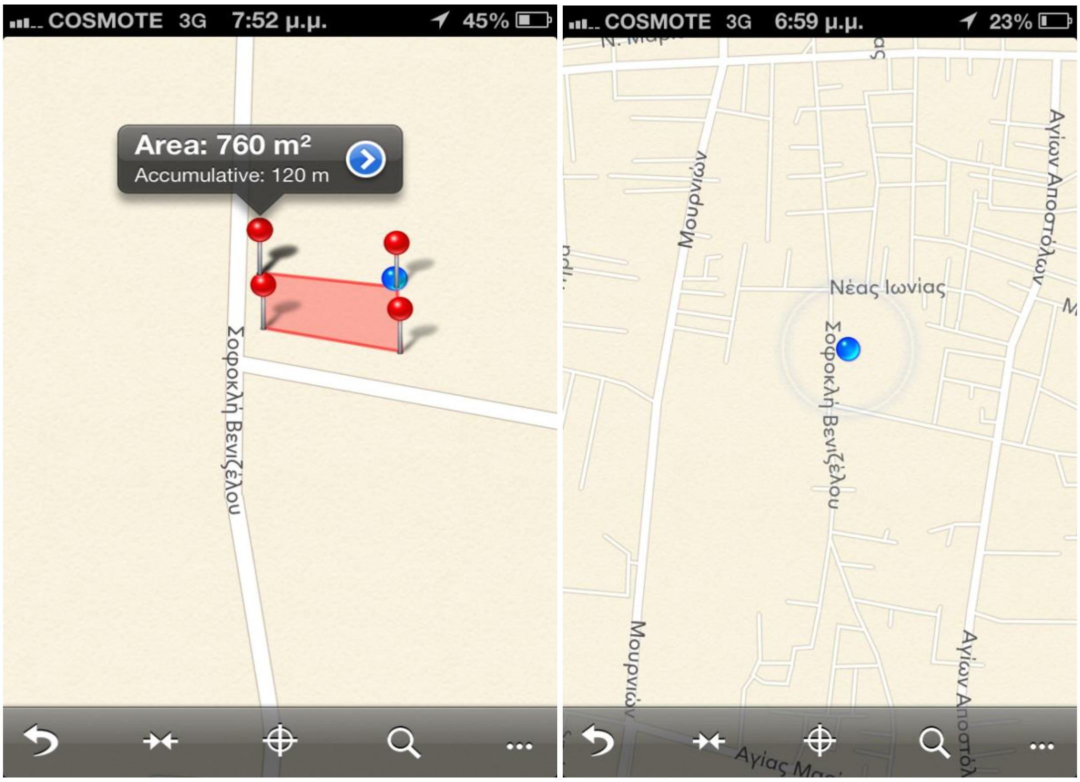


Figure 4-10: Different approaches in spatial data collection

The attribute data collection can be implemented with the aid of online databases, which can store and maintain the saved information. Until now, the declaration of property in Greece has followed the hard copy methodology. The owners have to fill in an application and submit it to the cadastral office. The specific process can be replaced by an online application via the web or by using applications in smartphones. It is clear that the VGI methodology is open and can offer various approaches depending on the different needs of each land administration project.

Data evaluation, as the third step of the workflow, should be guaranteed by the national mapping agency, which will also be responsible for the maintenance and storage of the data in its servers. Thus, one of the most important concerns in terms of viability – the difficulty of keeping data up to date – can be bypassed.

4.3.3. The stakeholders of the model

The model is based on the participation of citizens in an hybrid approach where citizens and property owners participate as volunteers and experts work as team leaders supervising the whole process. Thus, the hybrid approach involves both amateurs and experts for its implementation. In order to be successful, it requires the participation of locals, experts and NGOs, while the coordination of these parties should be carried out by the official mapping agency. Specific parts of the public sector should also participate in certain parts of the procedure.

The term “locals” refers to the landowners and volunteers who will participate in the cadastral surveys. Their participation should be based on data collection and editing during the first steps of the process and the acceptance of the result at the end of the cadastral survey. Citizens may collect not only spatial but also attribute data. The locals constitute the base of the pyramid that is given in Figure 4.11.

As already mentioned, undergraduate students should be actively involved in various stages of the process. Students should participate in training and workshops as trainers and will also help in data collection as team leaders. For example, students of SRSE may participate in data collection and students of Geography may participate in data manipulation. They should coordinate the process. This may serve as a practical exercise in their studies.

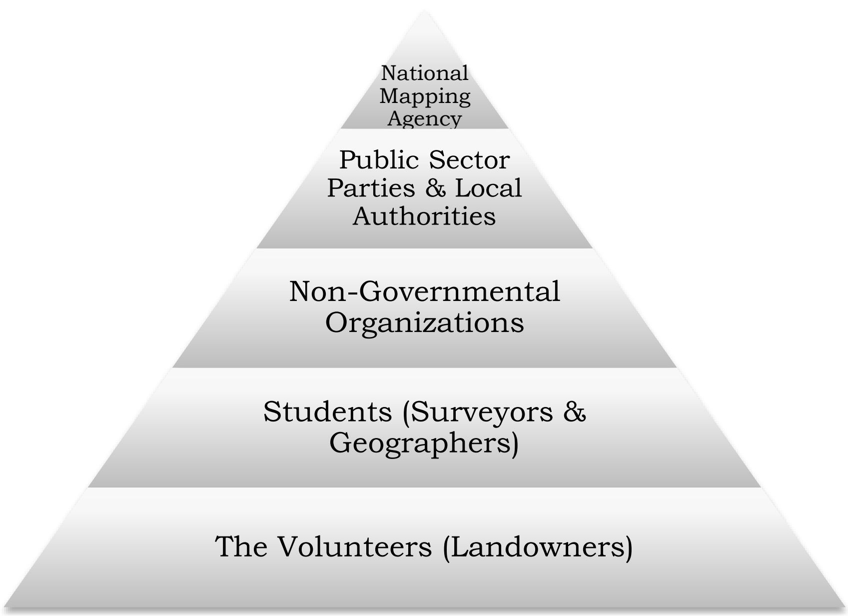


Figure 4-11: The stakeholders of the project

The next level of the pyramid refers to the NGOs who will train volunteers in data collection and editing. Their coordination highlights another important parameter: the cooperation of participating organizations and volunteers is crucial for the full advantage of human resources and technical innovation. Their interaction is also a parameter of success required not only at the beginning of the project but throughout.

Furthermore, the public sector should act to supplement these actors and provide the required equipment such as GPS and total stations, computers, vehicles and facilities. The local authorities should also play a critical role in data collection and they will contribute effectively to the collaboration among teams of local people at the stage of data collection, depending on their knowledge. This ensures that participants can contribute to specific tasks and stages of the data collection.

The national mapping agency should keep a supervising role and should be actively involved in all stages of the process. Coordination of the procedure, evaluation of the result and maintenance of the data in their server are their predominant tasks.

4.3.4. Coordination with the INSPIRE directive

The INSPIRE directive aims to launch a unique spatial data infrastructure within the European Union and will assist in policy-making across boundaries. The INSPIRE directive was first established on 15 May 2007. Commission regulation No 268/2010 of 29 March 2010 "Directive 2007/2/EC of the European Parliament and of the Council as regards the access to spatial data sets and services of the Member States by Community institutions and bodies under harmonized conditions", states among others, that institutions and bodies of the Community with access to spatial data sets and services should be harmonized. This is the basic argument against reluctant parties that reject the potential of citizens to participate in land administration (Official Journal of the European Union, 2010).

According to the official website (Inspire Directive, 2015), the directive will be implemented in various stages and will be fully implemented by 2019. Although INSPIRE is constituted by a series of technical issues and principally targeted at environmental projects, its main principles are summarized is six key factors that should be adopted by the proposed model.

- Data should be collected only once and kept where it can be maintained most effectively.

This key factor has already been taken into consideration, so that mistakes will be eliminated with the aid of the landowners who know the area of interest better than anyone else and the storage of the data has been assigned to the official mapping agency, which has powerful servers and space.

- It should be possible to combine seamless spatial information from different sources across Europe and share it with many users and applications.

This specific component coincides with the philosophy of crowdsourcing practices that firmly support open data and software, and data sharing within the various parties, organizations and citizens.

- It should be possible for information collected at one level/scale to be shared with all levels/scales; detailed for thorough investigations, general for strategic purposes.

The direct workflow that has been proposed in the previous sub-chapter services this need, especially if it is taken into account that crowdsourcing techniques are general practices to be applied in cadastral surveys for strategic purposes.

- Geographic information needed for good governance at all levels should be readily and transparently available.

The use of open-source software and the citizen participation makes the cadastral information open, transparent and available. This is one of the major decisions governments should take in order to proceed with this model.

- Easy to find what geographic information is available, how it can be used to meet a particular need, and under which conditions it can be acquired and used.

It is clear that the aim of this study is to satisfy the last requirement of the INSPIRE directive in general and support its implementation as a vital part of the coordination of the European parties in spatial data distribution.

4.4. Concluding remarks

A brief presentation of the Hellenic Cadastre project has been given to show how it works, its progress, its official process and what kind of deficiencies it faces, in order to find solutions to them. To date, the official mapping agency has worked in a strict model supervised only by experts and its progress remains slow in comparison to its cost and lifetime. The errors recorded in the on-going cadastral surveys – due to the fact that owners have limited role in the project – also cause anxiety about its timetable, the extra costs and its viability.

Based on this experience, the design of a potential crowdsourced model for cadastral surveys is attempted, taking into consideration the basic principles of the INSPIRE directive, the human resources, the process and the ideas that can be adopted as successful key factors from previous experience.

The proposed model constitutes a general process that may be applied or modified according to the special needs of the official mapping agency and can be adopted in various land administration issues in various countries. Its main innovation is based on the combination of current trends and previous experience in similar case studies. Its main advantage is stated not only through the participation of citizens in important decision making policies but also through its flexibility. There are still many concerns and parameters that have not yet been identified, quality and privacy queries that a conservative part of the society poses, or problems of credibility that make governmental bodies reluctant to use it. However, it is clear that the new crowdsourcing trend is not temporary and will continue to play a fundamental role in this recently begun revolution. The next chapters will focus on the application of the proposed cadastral model by testing various approaches and alternatives. The general outcome is condensed not in a unique solution but in a general idea that should be flexible and can be easily modified based on the needs of society and the available tools and funds.

The table below summarizes the main results of the fourth chapter.

➢ The most important project that is carried out currently in Greece is the Hellenic Cadastre. Its structure, budget, progress and importance are highlighted within this chapter.
➢ The HC project is presented and used as a guideline for the design of the new model, which may serve various land administration projects.
➢ The predominant lessons transferred into successful factors for the design of the potential crowdsourced model are: the workshops that will be incorporated at the beginning of the process, the recruitment of volunteers, the partnership of organizations, the combination of conventional and open-source software, participation from a distance and innovative techniques.
➢ The process of the potential model is a series of flexible and simple stages, which can be completed with the aid of new technologies, online dynamic maps, open tools and free-of-charge applications.
➢ The main innovation is focused on the participants, who are a mixture of landowners, volunteers, undergraduate students, NGOs, parties of the public sector, surveyors and the national mapping agency.
➢ The need for the potential crowdsourced model to coordinate the requirements of the INSPIRE directive is evident. Every single effort should be accomplished within the national and European general strategies and legal frameworks. The study supports this direction.

Table 4-2: Concluding Remarks of the fourth chapter

5. AN INVESTIGATION INTO CITIZENS' MOTIVATIONS

5.1. Introduction

The main goal and innovation of the fifth chapter is the identification of the true motivations of volunteers and the targeted incentives for a potential crowdsourcing participation in a governmental project such as a cadastral survey. All previous studies focused on general aspects of motivations so there was an obvious gap in the targeted motivations for land administration processes.

This chapter investigates volunteers' opinions about, and motivations for, potential participation in a cadastral project. The research focuses on the examination of a wide range of participants of various ages and educational backgrounds, composing an unbiased sample in Greece. A questionnaire was compiled in a Google platform and distributed to more than 250 volunteers. The volunteers were mainly questioned about their intention to participate in cadastral mapping and the potential motivations behind their participation. The research was carried out through the completion of anonymous questionnaires in an online platform supported by Google, adopting the snowball sampling methodology. The research first focused on (a) raising awareness and exploring volunteers' availability and their familiarity with new technologies; (b) identifying the reasons which would lead them to participate in cadastral mapping; and (c) volunteers' opinions about the efficiency of the official traditional cadastral surveying procedure.

The questionnaire was divided into three main categories: the first category focused on technical questions; the second on specific questions over the VGI phenomenon, targeted motivations and the HC project; while the last category included personal questions. 58% of the sample was female and 16% was engineers.

The findings indicated that the financial recession in Greece has affected society's opinion of voluntarism and free-of-charge participation in governmental projects. However, the general trend is positive and citizens realize the need for an accurate land administration system for fair taxation and property market functioning. The questionnaire is given in Appendix I (in Greek). The answers are held on the Google platform and are open to the public depending on the settings.

Table 5.1 indicates the main components of the fifth chapter.

➢ Investigation of general previous studies about volunteers' motivations and incentives carried out by the research community.
➢ Design and distribution of an anonymous questionnaire in a Google platform, which was divided into four sections.
➢ Investigation of volunteers' motivations behind potential participation in a cadastral survey.
➢ Participants' opinions about the Hellenic Cadastre project and the necessity behind it.
➢ Identification of volunteers' opinions over land administration issues.

Table 5-1: Predominant components of the fifth chapter

5.2. Related research and publications on volunteer motivations

In recent years many researchers have tried to understand participants' incentives for volunteerism. Although the VGI phenomenon is relatively recent and its parameters have not been analyzed in depth, there are numerous publications that describe citizens' motivations towards volunteerism generally. Clary & Miller (1986), Clary & Orenstein (1991) and Penner & Finkelstein (1998) are among the very first studies on this topic. The research sets its origins in the 1970s and was extended to the many cases and scientific fields of interest to the researchers.

Volunteerism as a movement, and as self-expression, has impelled researchers to carry out various studies on specific issues. The studies can be divided into three main categories according to their content: volunteerism in general, volunteerism in GIS and targeted volunteerism in specific geographic applications. The main innovation of this specific research is the focus on the motivations of volunteers in the field of cadastre by incorporating common reasons and exploring new ones. This is the first research to theoretically explore the motivations of citizens towards a volunteered governmental project.

Before VGI become a trend, research concerning volunteerism in general shed light upon the phenomenon. Papadakis *et al.* (2004) did research based on questionnaires among volunteer and non-volunteer, male and female, and service-oriented and non-service oriented majors and their motivations to volunteer. Their research was focused on a six-parameter Volunteer Inventory Function (VIF) by performing a series of t-tests on altruism, career, understanding, social, enhancement, and protection, as first introduced by Clary *et al.* (1998). The results indicated that values, understanding and enhancement were assigned significantly more to female rather than male participants, and those who had volunteered at some point in their life more than others. Many studies were based on this specific model and numerous publications have been evaluated its outcomes.

When Goodchild first introduced the term VGI (2007), he made the very first attempt to identify the motivations of volunteers manipulating Geographic Information by presenting two fundamental factors. The first one is based on the self-promotion that an individual hopes to gain from participation in the project. It is notable that after the creation of the Mapchester – mapping of the city of Manchester over a weekend by volunteers – the majority of the people asked for feedback about how much they had done (Perkins & Dodge, 2008). The second factor may derive from a personal satisfaction. Everyone feels satisfied by contributing to the completion of such an ambitious effort. Tulloch (2008) also considers that achieving a higher level of empowerment may be a considerable reason for participating in VGI projects such as OSM.

Another aspect that is posed by Sieber (2007) in her research "Geoweb for Social Change" concerns activism, which in fact is a significant worry according to her. It is unclear how one moves from a visualization environment to an active one. Various digital applications have proved this particular claim.

Haklay & Budhathoki (2010), in their presentation at the Horizon Infrastructure Challenge Theme Day, gave an overview of the main motivations that can activate volunteers to participate: fun, recognition, money, unique ethos, reciprocity and instrumentality are notable among the most common factors given in relevant studies. Instrumentality means that volunteers can serve an aim and reciprocity means that volunteers can act positively towards a positive aim. Both factors inspired the research of VGI in cadastre as a useful field of application.

The most recent research was carried out by Coleman (2010), who also provided his own list of factors, dividing them into positive/constructive and negative factors. In the positive factors, he listed altruism, professional or personal interest, intellectual stimulation, protection of a personal investment, social reward, personal reputation, self expression opportunity and pride of place. Among the negative factors, he listed mischief, social, economic or political agendas and malice/criminal intent. His other research, titled "Volunteered Geographic Information: The nature and motivation of producers" (Coleman *et al.* 2009), divided volunteers in five categories based on their knowledge and background. Thus, a volunteer can be neophyte, interested amateur, expert amateur, expert professional or expert authority and may get involved in various crowdsourcing actions based on his or her capabilities.

5.3. The practical application

The research behind the model was carried out from May 2011 to December 2011 in a six-month period of collecting opinions and responses anonymously, and from January 2012 to June 2012 when data was edited and results were evaluated (Basiouka & Potsiou, 2013). The period during which the research took place is extremely important, taking into consideration that Greece had asked for financial support from the International Monetary Fund (IMF) at the same time as this study asked citizens to participate voluntarily in a governmental project. Meanwhile, the unemployment rate reached 24.4% in June 2012, up from 23.1% in May 2012, which had increased 6.3% since May 2011 (Eurostat, 2012). In the same period, Greece had accepted a four-year special drawing rights (SDR) US$23.8 billion (about €18 billion) arrangement from the Executive Board of the IMF. According to the Annex of IMF (2012a) the recent economic developments were worrying: "Since 2009, Greece has been unwinding fiscal and external imbalances, but through deep recession. Real GDP has declined by more than 13% since 2009. Private investment led the downturn in 2009, while public retrenchment started only in 2010" (IMF, 2012b). It is clear that Greece was experiencing a crucial financial situation, close to an economic disaster, within the period that the survey was carried out, which affects not only social coherence but also citizens' trust of governmental projects and actions.

When the HC project started in 1995 few could predict how long it would last and how much money would be spent. However, with the Greek economy at such a crisis point, there is an urgent need for an updated land administration tool to support fair taxation and property markets.

5.3.1. The nature of the research

This research has combined many and different aspects of previous research, especially in terms of structure and content. The Volunteers function inventory (VFI) model includes six main factors, which were used for the development of the questionnaire: the values factor, the career factor, the understanding factor, the social factor, the enhancement factor and the protective factor. For the current research the VFI was simplified into four main categories expressing the main reasons for participation in a cadastral mapping [Figure 5.1]. The values factor expresses altruism and was named “altruistic reason”. The career factor includes career reasons as the title suggests. The understanding factor, which includes skills practicing, was merged with the career factor. Social function was also merged with the enhancement and protective factors incorporating social awareness, relaxation, personal satisfaction and self promotion. These three categories were generally named as personal reasons. A new category was also created containing targeted, specialized reasons. A four-dimensional framework for theoretically approaching volunteers’ motivations was created by researchers in an effort to concentrate, simplify and fit the VFI model (Clary *et al.*, 1998) to the requirements of targeted research for a governmental VGI project.

The four categories were compiled from motivations presented by the authors of the publications above or were created by the researchers in relation to aspects of this study’s context. Among the most important factors that have been taken into consideration in all publications are those that can be divided primarily into two main categories: altruistic and egoistic motivations.

The motivations for participating in cadastral mapping are given below:

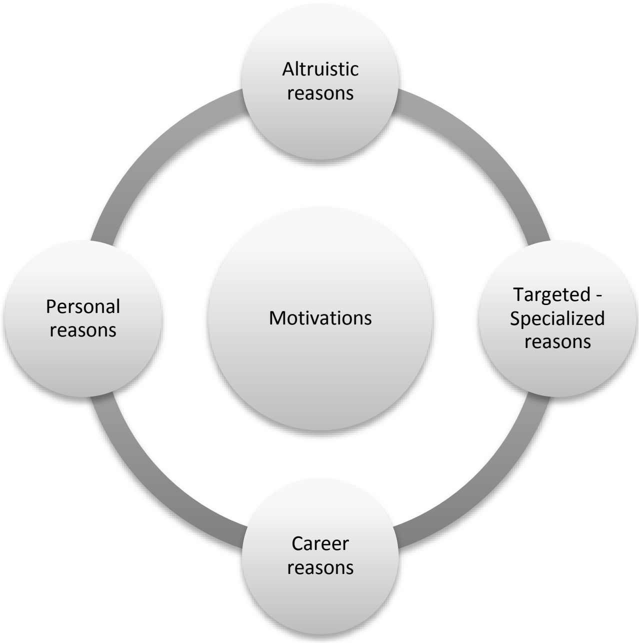


Figure 5-1: Main reasons for participating in cadastral mapping

A. Altruistic motivation as a contribution to society, which means assisting in any manner without any claim of exchange.

B. Targeted and specialized questions on cadastral process. The volunteers were asked about their willingness to participate to save cost and time by collecting accurate spatial data free of charge and correcting the lack of spatial data in the area of interest.

C. Career reasons such as career investment and technical specialization in relation to the specific field.

D. Personal reasons and more specifically: personal satisfaction, relaxation, self-promotion and introduction to social networks, social reward and self-promotion.

5.3.2. The content of the research

A questionnaire was designed in a Google platform and 250 individuals completed the online form. It was divided into four main sections consisting of general, special and personal questions [Figure 5.2].

The first section consists of general technical questions as a way to determine the familiarity of the citizens with technical aspects: use of personal computers, broadband Internet, cell phones with Internet connections; use of social media such as Facebook, LinkedIn, etc.; and use of dynamic maps. As McLaren (2011) has emphasized, the expansion of smartphones with GPS functionality have given great assistance to crowdsourcing techniques.

The second section is focused on the willingness of citizens to participate voluntarily in cadastral mapping and the potential motivations that could lead them in this direction.

The third section addresses how citizens perceive the Hellenic Cadastre; how concerned and aware they are of its necessity, role, cost, funding and perspectives.

The last section includes personal questions concerning the respondent's gender, age, educational background and the potential professional connection.

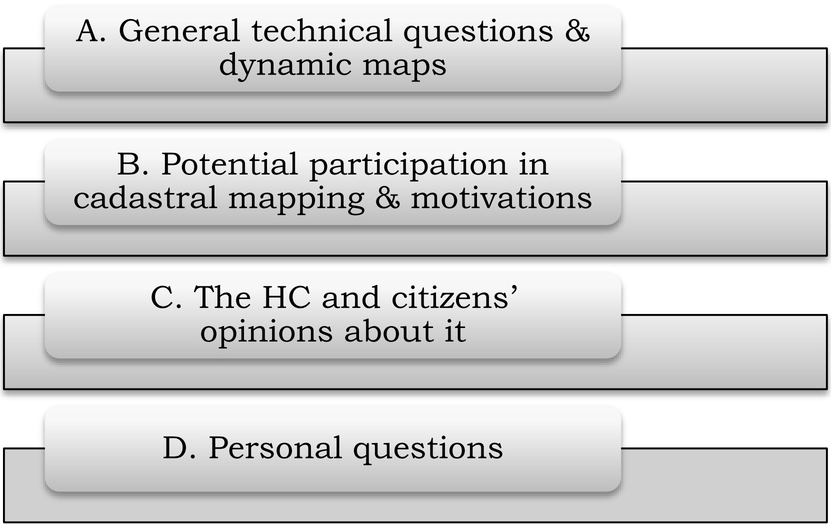


Figure 5-2: The content of the research

The questionnaire was designed using closed format questions so that respondents' answers could be restricted by specified boundaries and the replies could be easily categorized and classified statistics exported. Questionnaires using open-ended questions are more time consuming, hard to categorize and some questions may remain unanswerable. The main categories of closed-end questions that were posed are **close-ended dichotomous questions, close-ended likert questions and** close-ended scale questions.

The main questions are given in the text box in Figure 5.3:

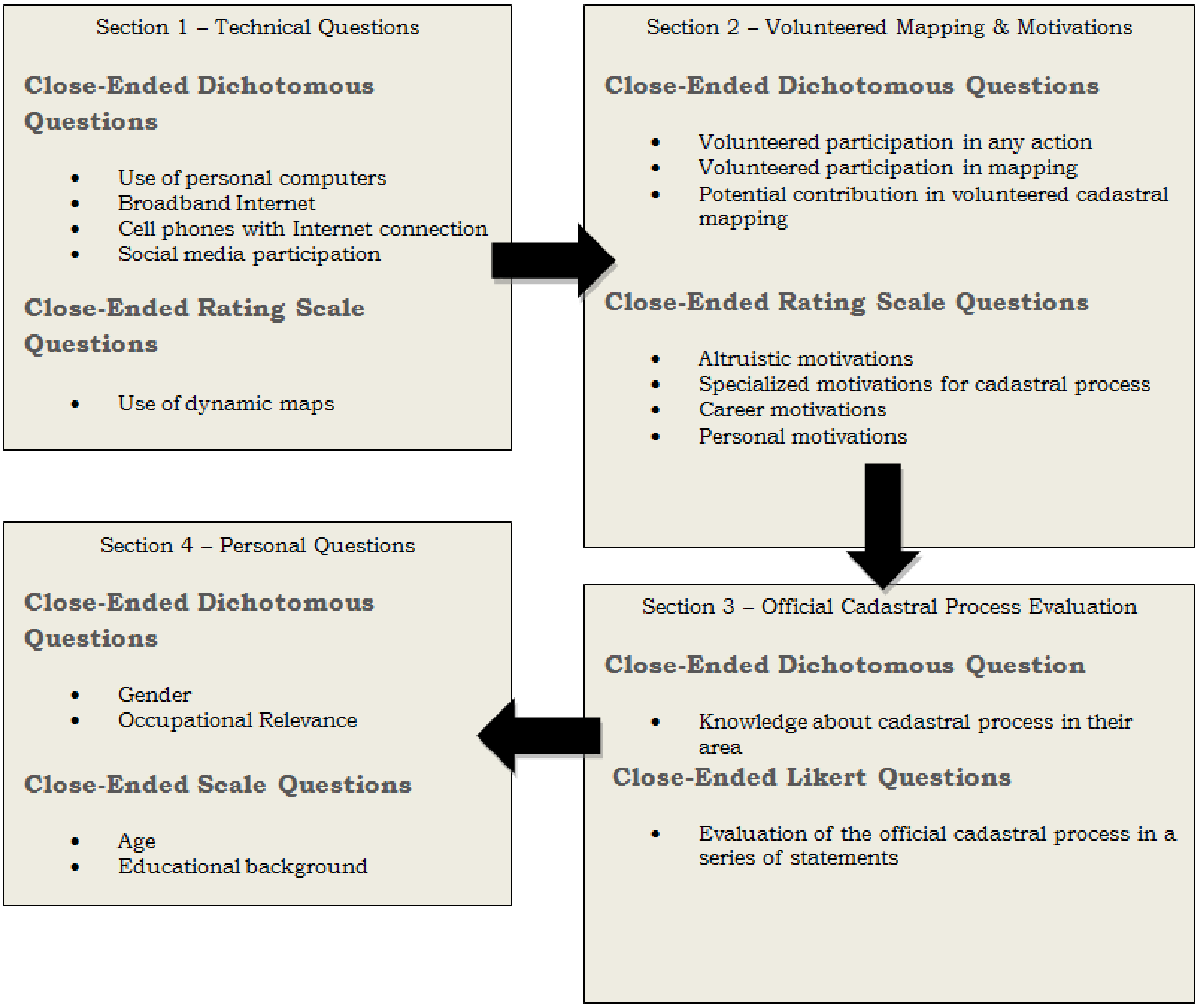


Figure 5-3: Main reasons for participating in cadastral mapping

5.3.3. The sample of the research

The sample was selected by using the exponential non-discriminative snowball sampling methodology and covered a wide range of age and educational backgrounds spread across all Greek jurisdictions including urban areas, the capital city of Athens and rural areas as well. The questionnaire was shared by the researchers among undergraduate students of the SRSE, employees occupied in the public and private sectors, engineers (16% of the total sample), colleagues and neighbors of the researchers and a wide range of people in the social environment of the researchers [Figure 5.4]. This type of sampling technique works like chain referral. The exponential non-discriminative snowball sampling methodology was adopted due to its advantages: it is a quick, inexpensive and efficient methodology which allows researchers to reach populations that are difficult to sample.

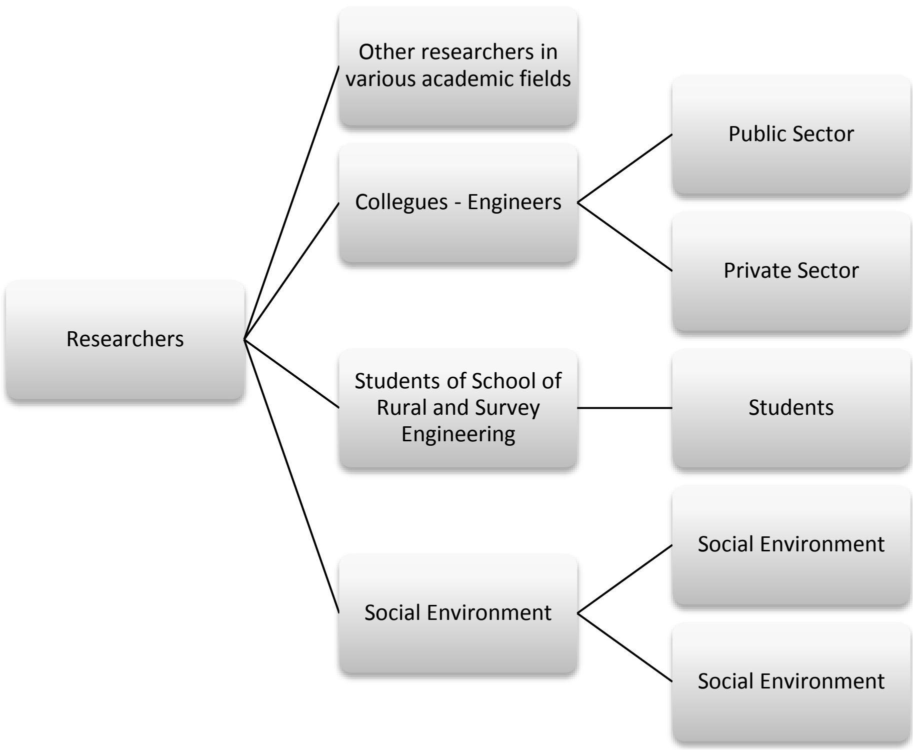
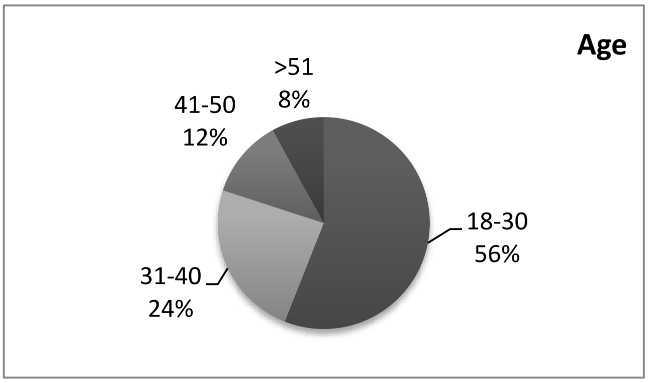


Figure 5-4: The exponential non-discriminative snowball sampling of the research

Citizens who live abroad were asked to participate in the research covering 2.5% of the total sample so that the answers might vary based on external incentives. The percentage of women was higher than men: 145 women and 105 men participated on the experiment. The majority of the sample was 18 to 30 years old in an effort to approach those who are more familiar with new technologies [Figure 5.5]. The sample in all other age categories decreased with age.



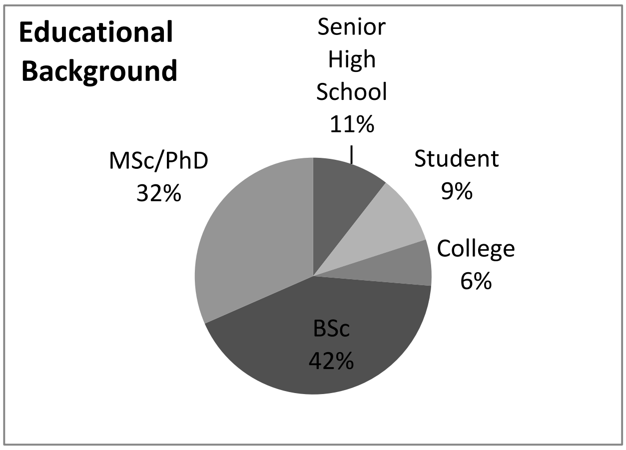


Figure 5-5: The age and the educational background of the sample

5.4. The results

5.4.1. Technical responses and dynamic maps

The research was firstly focused on technical aspects in order to identify citizens' familiarity with the new technologies. The first part of the survey is an introduction to GI before the participants are asked about the specialized field of VGI.

It is remarkable that in the first section, the majority answered positively. All respondents have a personal computer and 96% have a broadband connection while 60% retain an account on social media pages and have a GPS, proving the great increase which mentioned in the BroadBand Report of the Observatory for the Greek Information Society (2012).

The extreme majority, 94%, also answered positively about the use of online maps. Between the six most common maps in Greece (Google Maps, Bing, OSM, DriveMe Terra and Navigation.gr Maps) the table below indicates that Google is the leader in use and preference far beyond its competitors. The specific maps were chosen among numerous others, not only because they are popular but also because they have not been derived by mashup maps. The spatial data used in each map is primordial and was not derived from different sources.

Table 5.2 summarizes the extent to which the sample uses these online maps.

	Google Maps	Bing Maps	OSM	DriveMe Maps	Terra Maps	Navigation.gr
Not at all	1%	81%	86%	56%	91%	75%
To little extent	7%	6%	5%	10%	1%	13%
To some extent	20%	6%	4%	16%	4%	6%
To a large extent	24%	5%	3%	11%	3%	4%
To a very large extent	49%	1%	3%	7%	1%	3%

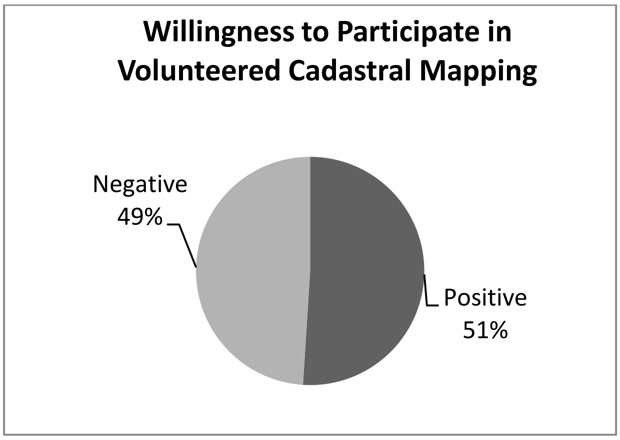
Table 5-2: Extend of use of specific dynamic maps

5.4.2. Are Greeks willing to participate in VGI governmental cadastral mapping projects?

Starting the second section of the research, respondents were asked if they have ever participated voluntarily in any action, if they have especially participated in mapping and if they would potentially participate voluntarily in cadastral mapping. Overall, 56% of the sample has never participated voluntarily in any action. Only 3% of the participants have voluntarily participated in mapping and 51% of the sample is positive about participating in cadastral mapping although it is a totally new activity for them.

The results indicate a positive trend towards cadastral mapping, which is increased among citizens who have already participated in an action or project voluntarily. All these citizens have already adopted a culture of contribution and 55% of them might participate potentially in cadastral mapping. The percentage is encouraging if it is taken into account that the majority were volunteers at the 2004 Olympic Games, which was the most important national goal of the last twenty years before Greece fell into a great economic recession.

However, most impressive is the percentage of experts who are willing to participate in cadastral mapping. Almost 77% of surveyors, GIS specialists and cartographers, generally young, are positive about potentially participating in mapping [Figure 5.6]. The specific results prove not only the potential of expert volunteers as team leaders in targeted volunteer actions (Basiouka & Potsiou, 2012b) but also verify Adlington's (2011) research, which showed that in East Central Asia the World Bank Land Administration Management projects have succeeded in the greatest land reform the world has ever seen because they have been guided by experts who were open to helping, without being wedded to traditional methods and high levels of accuracy, and were willing to be practical and meet the needs of the society. The results were constant between men and women although a gradual elimination of interest was mentioned in accordance with increasing age.



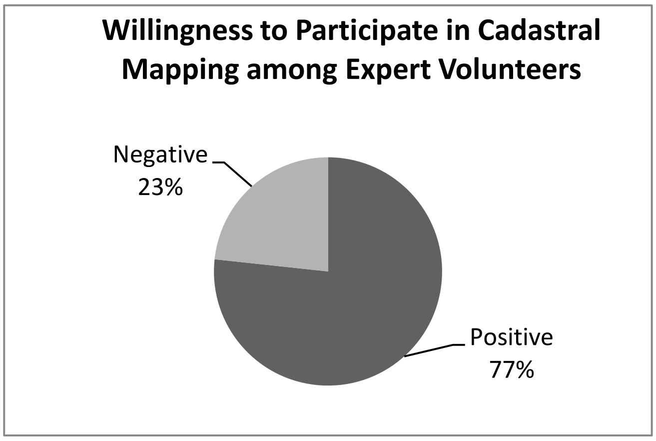


Figure 5-6: Willingness to participate in cadastral mapping

5.4.3. Motivations behind participation in cadastral mapping

All previous research has primarily focused on altruistic aspects (Coleman *et al.* 2010, Papadakis *et al.* 2004, Haklay & Budhathoki, 2010). As Clary & Miller (1986) first underlined, altruism positively affects the length of service offered by volunteers. Altruism was the first main category that was also evaluated in the current research. The given answers were encouraging, as 63% of participants would participate to a large or very large extent as a manner of contribution to society. Only 4% would not participate at all or to a little extent offering the same incentive.

Clary *et al.* (1998) have reported that volunteers who receive benefits are more willing to participate in voluntary projects. The study indicated that volunteers were willing to participate in contributory cadastral mapping in order to speed up the official process to some extent (32%) and to a large extent (30%); and in order to minimize its cost to a large extent (26%) and to very large extent (22%).

Table 5.3 summarizes the targeted responses below.

	Quicken the official process	Minimize the cost of the official procedure	Acquiring free geospatial data	Fill the gap of reliable geospatial data
Not at all	8%	14%	14%	10%
To little extent	8%	16%	8%	16%
To some extent	32%	24%	24%	24%
To a large extent	30%	26%	31%	29%
To a very large extent	22%	22%	24%	20%

Table 5-3: Volunteers' responses to specified questions about cadastral mapping

Regarding career reasons, the results are controversial indicating the real socio-economic situation of Greece. The majority (35%, "not at all") considers that participating in a governmental VGI project is not a proper way for career advancement. On the contrary, one out of four participants supports the opposite; that participating in such a VGI project could broaden horizons and improve chances of gaining a relevant position. The citizens are divided into two main categories based on the security they receive from their career field. However, participation is considered as a great opportunity for gaining technical knowledge in the specific field (60%) and for developing practical skills. It is clear that the levels of unemployment have increased citizens' interest in new fields. As Clary & Snyder (1999) summarized, career reasons are those that could activate volunteers to work in a scientific field that they might prefer.

Among the personal reasons considered in the questionnaire, the predominant one is personal satisfaction, where one out of three volunteers might contribute to a large extent. However, it is noticeable that volunteers might not contribute to cadastral mapping for all the other personal reasons given in the survey. Incentives such as stress elimination, self-promotion and introduction to social networks were negligible in impact. This is not surprising, if it is taken into consideration that targeted participatory mapping has to serve specialized needs. In all these personal cases the majority, which varied between 43% and 63%, answered negatively to a perspective of participation driven by specific motivations. Thus, it is clear that targeted research like this, which is focused on a specific aim, cannot be advanced by general personal motivations.

The graph summarizes what volunteers broadly support or, in other words, what would potentially motivate them [Figure 5.7].

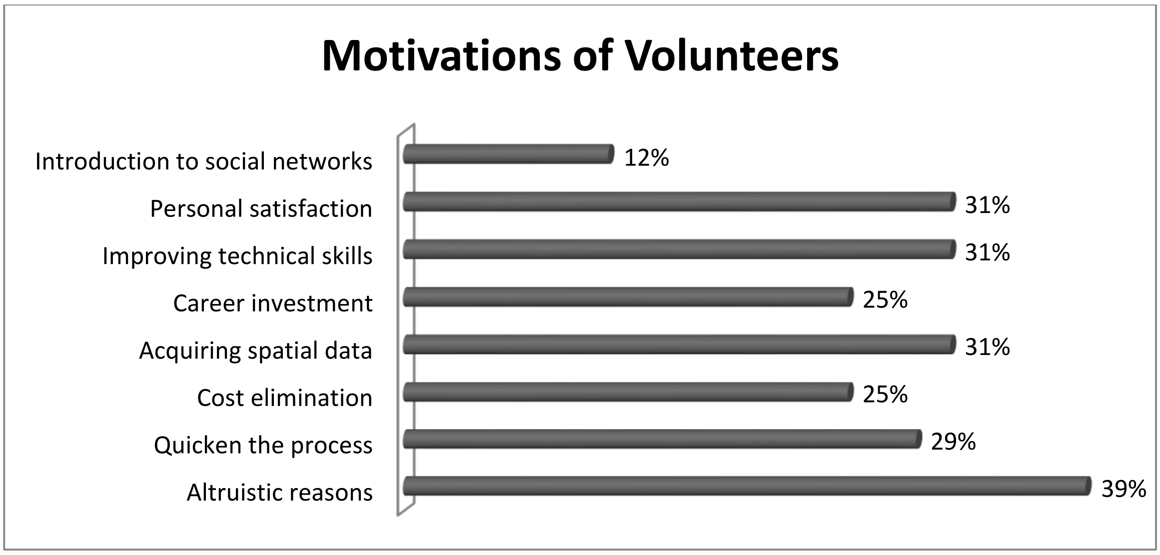


Figure 5-7: Broad motivations of volunteers

5.5. Oriented Land Administration initiatives in participatory mapping

The main objective for introducing crowdsourcing techniques in cadastral data collection is to activate local citizens and rights holders, as these are the ones who best know the existing situation in the field (tenure and boundaries), in order to provide more accurate and cheaper interim cadastral maps and to shorten the duration of the procedure, especially in rural areas. However, the questionnaire focused on more general issues and did not go into details relevant to the above problem, while the sample of participants was not affected by this problem. The questionnaire indicated that participants recognize the value of an accurate LAS as a sign of a civilized society that protects public and private ownership in a framework of fair taxation, and supports property markets and economic development.

It is notable that 47% of the participants unconditionally support this concept, while 78% of the sample is positive about this statement (1). Furthermore, eight out of ten citizens agree that the existence of a cadastre will eliminate squatting on state land and will solve all controversies of landownership, while guaranteeing private properties (2). 66% of citizens also believe that when the compilation phase is complete the economy will start benefitting (3) and more specifically 60% of them agree that there is a need to accelerate the compilation procedure (4). The concern is higher in aspects like fair taxation; almost seven out of ten citizens thinks that the Cadastre is created for taxation purposes and will bring fair taxation (6); 43% of citizens characterize the official process as time consuming and expensive (5). It is remarkable that four out of ten have neither positive nor negative reactions to these two last statements, indicating ignorance about the subject.

The graph summarizes the given answers by the sample broadly in agreement with this section [Figure 5.8].

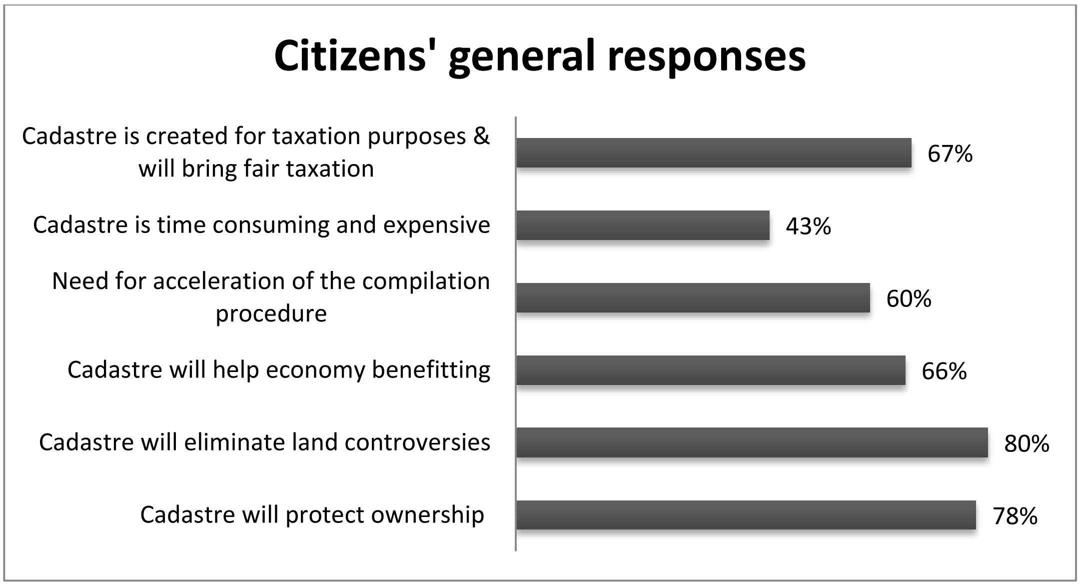


Figure 5-8: Citizens' general responses

5.6. Concluding remarks

It is clear that the motivations of volunteers vary a great deal. Volunteers may contribute to the same research motivated by various incentives. However, it is encouraging that among the principal motivations are altruism and a wish to improve the official process. Although Greece is in a difficult socio-economic situation, the fundamental motivations are focused on general improvement to land administration and cadastral processes. Participants recognize the need for an accurate LAS as a tool for ownership protection and the property market.

Targeted reasons are found behind citizen participation. Elimination of time and cost are the fundamental factors. Researchers' experience indicated that the theoretical approach differentiates slightly from the practical one. Participants' desire for property transactions and the elimination of registration fees can be positive factors, speaking practically. Participants' desire to help society is the principal incentive, theoretically. Their positive recognition of the utility of a cadastral system was in contrast to their suspicion towards the official procedures, which turns them from being reluctant to potential participants in mapping.

Although participants were quite divided into two main categories of either participating voluntarily in mapping or not, the majority was positive towards this. The percentage of positive answers was significantly higher among the younger participants, the citizens who had a previous voluntary experience, people who do not work in the public sector and do not have guaranteed job positions and experts such as engineers, surveyors and GIS analysts.

Among the most positive results of the survey is citizens' comprehension of the need for a proper LAS and the necessity of its implementation.

Table 5.4 indicates the predominant results of the survey.

➢ There is no great differentiation between men and women in terms of potential participation in crowdsourced cadastral mapping.
➢ There is no great differentiation between participants who live abroad and those who live in Greece when it comes to potential participation.
➢ However, young participants were found more willing to potentially participate in a cadastral survey than older participants.
➢ The participants who answered negatively about participatory mapping where those who have never participated voluntarily in any action, and find the whole process time consuming and incomprehensible.
➢ The sample was found balanced in terms of potential participation in cadastral mapping. Although a positive trend prevailed for 1%, the financial crisis has primarily affected citizens' trust towards governmental projects.
➢ Within the targeted motivations, the majority of the citizens would participate voluntarily so that the cost could be reduced, the process quickened and the whole project of the Hellenic Cadastre concluded.
➢ The most positive remarks include the altruistic reasons that could lead respondents to potential voluntary participation. Among other reasons personal satisfaction, improving technical skills and acquiring spatial data for free are included.
➢ Furthermore, citizens seem to understand the necessity of a proper LAS as a tool for fair taxation, that could also eliminate land disputes among the owners and protect private ownership.

Table 5-4: Concluding remarks of the fifth chapter

6. TESTING CROWDSOURCING TECHNIQUES IN URBAN AREAS

6.1. Introduction

The sixth chapter investigates crowdsourcing techniques that can be implemented in urban areas. The research investigates those reforms, which are essential so that cadastral surveys can be quicker and cheaper, by taking into consideration the required accuracy. The research plan applies different methodologies, recruits young people and students who are familiar to new technologies and tests various approaches that may fit in urban areas. During this stage of the research, two different experiments of participatory mapping were carried out for cadastral purposes in areas with continuous construction and big block of buildings in the city center of Athens. In technical terms, the study investigated three different components that play crucial roles in cadastral mapping in urban areas and constitute the basic parts of the two experiments: GPS, web mapping with the aid of orthophotos and OSM. The two different practical applications were designed and applied in two different areas of the city of Athens.

The first experiment took place at Kallithea municipality, close to the city center of Athens, where nine volunteers participated and seven blocks of buildings where traced. A handheld GPS and an iPad were used in the implementation of the experiment. In terms of accuracy, the experiment failed to address the requirements posed by the official mapping agency due to GPS discrepancies so the procedure was repeated with online mapping tools provided by the agency. The online mapping took place in the field with the aid of an iPad and the digitization was done on orthophotos that provide spatial analysis to 20cm in urban areas. The findings of the first experiment indicated a great flexibility and various potential solutions that could be adopted in official cadastral processes with the aid of new technologies.

The second experiment was carried out in an extended part of the historic city center of Athens with the participation of twenty undergraduate students of the School of Rural and Surveying Engineering where ninety five blocks were enhanced with attribute data and forty five blocks were enhanced with spatial data by using OSM. The researchers explored the capacities of the dynamic map in two steps: (a) in a section where the polygons of the buildings already existed on the map, so they had to improve it with attribute data, and (b) in another section where no relevant polygons existed. The research was based on the various approaches and the freedom that the OSM offers to users.

Both experiments showed that declaration of properties from a distance, digitization on web maps and adoption of new technologies in urban areas can satisfy the required accuracies and offer an alternative, open option that may be transformed into a crowdsourced model. In particular, concerns over the result produced can be eliminated in terms of accuracy and reliability. The results indicated a new trend which is more flexible to use and may replace the hard copy submission of declarations during the first phase of the cadastral survey, while it may simplify the official procedure for spatial data collection which constitutes the second phase of the cadastral survey. The main innovation of the research is focused not only on the proposed process but also on the opportunity to manipulate spatial data from a distance. The evaluation of both experiments was applied in collaboration with the citizens who participated voluntarily and were interviewed afterwards. The research team and participants recorded the strengths and weaknesses of each experiment. The specific evaluation was adopted in terms of an open dialog with the volunteers and a flexible model.

Table 6.1 indicates the main targets of the sixth chapter.

➢ Investigation of the alternative for a crowdsourced cadastral survey model in urban areas with attending building construction and large blocks, where land measurements are totally replaced by digitization on orthophotos and use of dynamic maps.
➢ Design and implementation of two different practical experiments with the aid of new technologies and web tools in two different urban areas.
➢ Recruitment of young people, undergraduate students and locals as participants in the experiments.
➢ Adoption of web-mapping tools and online maps. Use of the first crowdsourced online map, OSM, for cadastral purposes.
➢ Evaluation of the process and the experiments by participants.

Table 6-1: Predominant components of the sixth chapter

6.2. Relevant research and publications on GPS and OSM accuracy

6.2.1. Previous international research on GPS accuracy

The methodology that is used for the collection of data using a handheld GPS is known as absolute kinematic positioning (Basiouka, 2009). The term absolute refers to a single receiver that is needed for the collection of the satellite signal and the determination of the position (Jekeli, 2000). Van Sickle (2001) says that kinematic positioning is developed from GPS that are in motion during the recording of the positional information. Pacione (1999) notes that kinematic techniques are used for the collection of positional information while on move. The most representative examples are in the survey of footpaths or on board cars. Ghilani (2008) underlines that kinematic positioning is appropriate in mapping. However, Pacione (1999) is the first to have underlined that this method is appropriate for determining the position of boundaries by walking around their perimeter.

In general absolute kinematic positioning is primarily used for navigation and the accuracy varies up to a few tens of meters. Its first advantage is that data is collected in a relatively short time. Moreover only a single, low-cost GPS device is needed. The main disadvantage is that a few errors remain due to the use of a single receiver. Otherwise errors such as atmospheric interference could be eliminated. Moreover, kinematic positioning is vulnerable to multipath and obstructions to satellite signal [Figure 6.1].

One way to reduce the inaccuracies is by averaging the positions recorded over a given time period. In general, GPS accuracy is also dependent on the average time of data collection. The main query that is posed is how long a receiver must occupy a location in order to achieve a particular accuracy. According to the best-case scenario, the required occupation time must be at least one second (Gilbert, 2003).

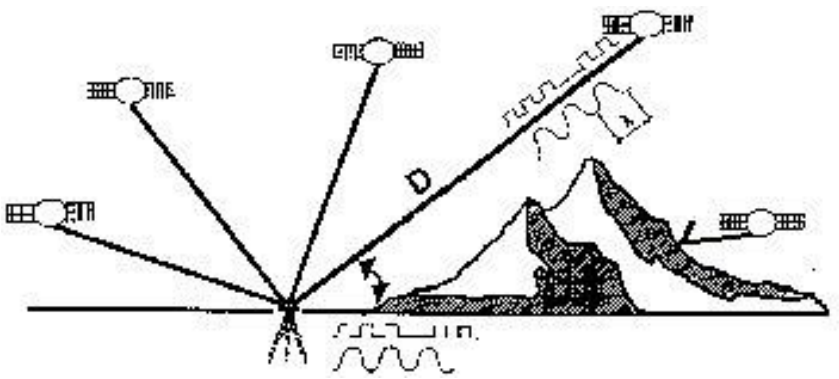


Figure 6-1: Real time kinematic positioning (source: Génie civil- Topographie: Positionnement par satellites, 2009)

Furthermore, different devices do not offer the same accuracy. Not just instrumental errors but personal ones can also affect the quality of the measurements. Wing (2005) compared six handheld GPS devices and he found that the positional errors vary to a significant level. More specifically, the positional error varied from 1.4 meters for the GPS map 76S to 19.6 meters for the Meridian Platinum.

GPS Errors

In general, the errors are divided into three main categories according to their source (Ghilani & Wolf, 2008):

- Natural errors result from atmospheric effects such as wind, temperature, humidity, moisture, and so on.
- Instrumental errors may be caused due to instrument imperfection or due to the individual movement of specific parts. According to Ghilani & Wolf (2008), these errors can be eliminated by implementing specific surveying methodologies or formulae.
- Personal errors may occur due to the observer's faults or omissions. These errors are unpredictable and detailed checks are required for their reduction.

However, there are two main errors that include all the above categories: random and systematic errors:

- Systematic errors are also called cumulative errors and they depend on the surrounding environment, the observer and the instrument. Systematic errors follow mathematical models and they remain stable if the circumstances do not change. Thus if the conditions are known, corrections can be applied to the observed values.

- Random errors may also be named accidental or compensating errors. They can be found in all measurements and they remain after having eliminated systematic errors. Their existence does not depend on the above reasons. In general these errors are unexpected and they follow the law of probability. They cannot be reduced or eliminated in a certain way. They only can be estimated by using least square analysis (Ghilani & Wolf, 2008).

The GPS errors that affect accuracy performance are divided into three main categories based on their derivation. Each category has a unique characteristic and the errors fluctuate from 1 meter to 10 meters.

According to Lachapelle (2007), the distinction of the errors and their magnitude in terms of user equivalent range errors (UERE) at the 95% probability level is:

- Satellite-based errors (orbits, clocks, group delays), 5–10 m
- Residual propagation errors (atmosphere, multipath), 5–10 m
- Receiver-based errors (antennas, clocks, interchannel biases, noise), less than 1 m.

GPS clock error is one of the most frequent errors and it is observed in each measurement. The error occurs due to the cheap mechanism that it is used in their production. The material is usually quartz. The clocks are used for correcting the satellite's pseudorange, which is needed for the exact calculation of the distance between the satellite and the observer. In general, standard values for the correction of a specific error are provided. Cross (2008) notes that broadcast clocks have an error of up to 2 meters and that post-processed clocks are estimated to the level of a few centimeters.

GPS ephemeris error occurs due to the difference that may arise between the actual position and velocity of the satellite and the one calculated. In general the ephemeris provides information about the actual and the future position of the satellite. All this information is known as Keplerian predictions. According to Cross (2008), the broadcast orbit predicts positions with up to three meters error. The predicted precise ephemeris is also at about 10 cm level and the post-processed precise ephemeris is at about 2 cm level.

Ionospheric error is inversely proportional to the square of frequency and occurs due to the delay of the L1 and L2 signals through the ionosphere. In general, the delays of the signals are due to charged particles. The size of the error varies a lot and may fluctuate from 0 to 100 meters depending on the time of the day, the elevation angle, the latitude and the sunspot cycle. In some cases ionospheric error leads to the total loss of tracking. 99% of the error is eliminated with dual frequency. Single frequency receivers use models to erase or ignore it.

Tropospheric error occurs due to the delay of the L1 and L2 signals through the troposphere. The main uncertainty is due to water vapour. However other factors include the temperature, the humidity, the angle of transmission through the atmosphere and the atmospheric pressure. According to Cross (2008), tropospheric error is estimated at up to 2.5 meters in zenith and at 12 meters at 10^{o}. 90% of this error can be modelled by specific formulae and approximately 99% can be estimated as a part of a solution.

Multipath error is considered by Giordano (1995) to be the principal source of location errors in an urban environment. The multipath propagation phenomenon depends on proximity to reflecting surfaces. The signal incurs multiple reflections during its travel from the satellite to the receiver. Therefore the signal takes longer to reach the receiver than it should. Prasad and Ruggieri (2005) note that the effect of several paths causes the presence of multiple phased and attenuated replies of the main signal (referring to the signal with the line of sight path) on the receiver side. As a consequence the signal quality is affected. Cross (2008) notes that the error may be up to five meters. However, it rarely exceeds two meters. In general, it is ignored. Otherwise special mitigation techniques are implemented for its elimination.

Taking into account the specific restrictions, GPS receivers have limited capacity for measuring in some environments, such as indoors, underground, under heavy tree canopy, in urban and natural canyons. Noise errors may also occur due to strong radio transmissions or power radio transmitter antennas around the device (Prasad & Ruggieri, 2005). However, their error is not considerable. It is usually ignored and it cannot be predicted. As an inexpensive and easy-to-use tool, GPS was adopted in two out of the four experiments carried out in urban and agricultural environments with specific restrictions and results.

6.2.2. Assessing OSM quality

Numerous case studies have been carried out in various European countries investigating the quality of OSM. United Kingdom, Switzerland and Greece are the first countries where the quality offered by OSM was evaluated. Generally, open software that may have derived from volunteer contributions brings quality concerns. Research carried out by Stark (2010) in Swiss comparing the quality of the OpenAddresses to the Open Web Map Services indicates the trend in this direction.

The Quality principles provided by the International Organization for Standardization standard ISO 19113: 2003 were adopted so that the accuracy of OSM could be evaluated. More precisely, the technique designed by Hunter & Goodchild (1997) was used for the estimation of positional accuracy, which is a major component of spatial evaluation for linear features. The specific approach was applied in all case studies.

The United Kingdom is where OSM first launched so it is predicted to be one of the best-mapped areas. The first research performed by Haklay (2010b) was extended by Ather (2009) and improved by Basiouka (2009). OSM was assessed compared to official datasets such as Meridian 2 and Integrated Transport Network Layers of Mastermap. Generally the quality of OSM was found to be fairly accurate in all case studies. The percentage of positional accuracy was more than 80%, and in South London approached 90%. Length completeness indicated that OSM road length is 95% of ITN road length and 69% of Meridian 2 road length. ITN data is considered to be the most up-to-date and accurate provided by the Ordnance Survey in United Kingdom. Finally, the number of volunteers was considerable especially in central areas proving that with a set of more than five volunteers in each 1 km^2 area, accuracy does not change dramatically (Haklay *et al.*, 2010).

In Switzerland the first research performed by Ueberschlag (2009) was focused on the canton of Geneva. The data provided by OSM was compared to the official data of the SITG service of Geneva and the TeleAtlas Company. The results indicated a modest trend with minor differentiations. The number of volunteers is considerable and the geometric accuracy and completeness is good. All the other aspects including attribute accuracy and completeness were moderate.

In Greece, research carried out in Athens (Kounadi, 2009) proved that the OSM project is an accurate tool offering a positional accuracy of more than 89% compared with the HMGS data, which is the official cartographic service. The dataset was a georeferenced raster grid tile of 1:10,000 scale that covers a 33.6 km² area around the center of Athens. The tested data was evaluated by comparing it with the official data provided by the Hellenic Military Service. The length completeness was found to be of 88% accuracy and the name accuracy was more than 87%. The two quality aspects where OSM was found to have low levels of accuracy is the name completeness and type accuracy, which was 26% and 33% respectively. The main reason of this discrepancy is the adoption of data from Yahoo imagery where names cannot be copied due to copyright restrictions.

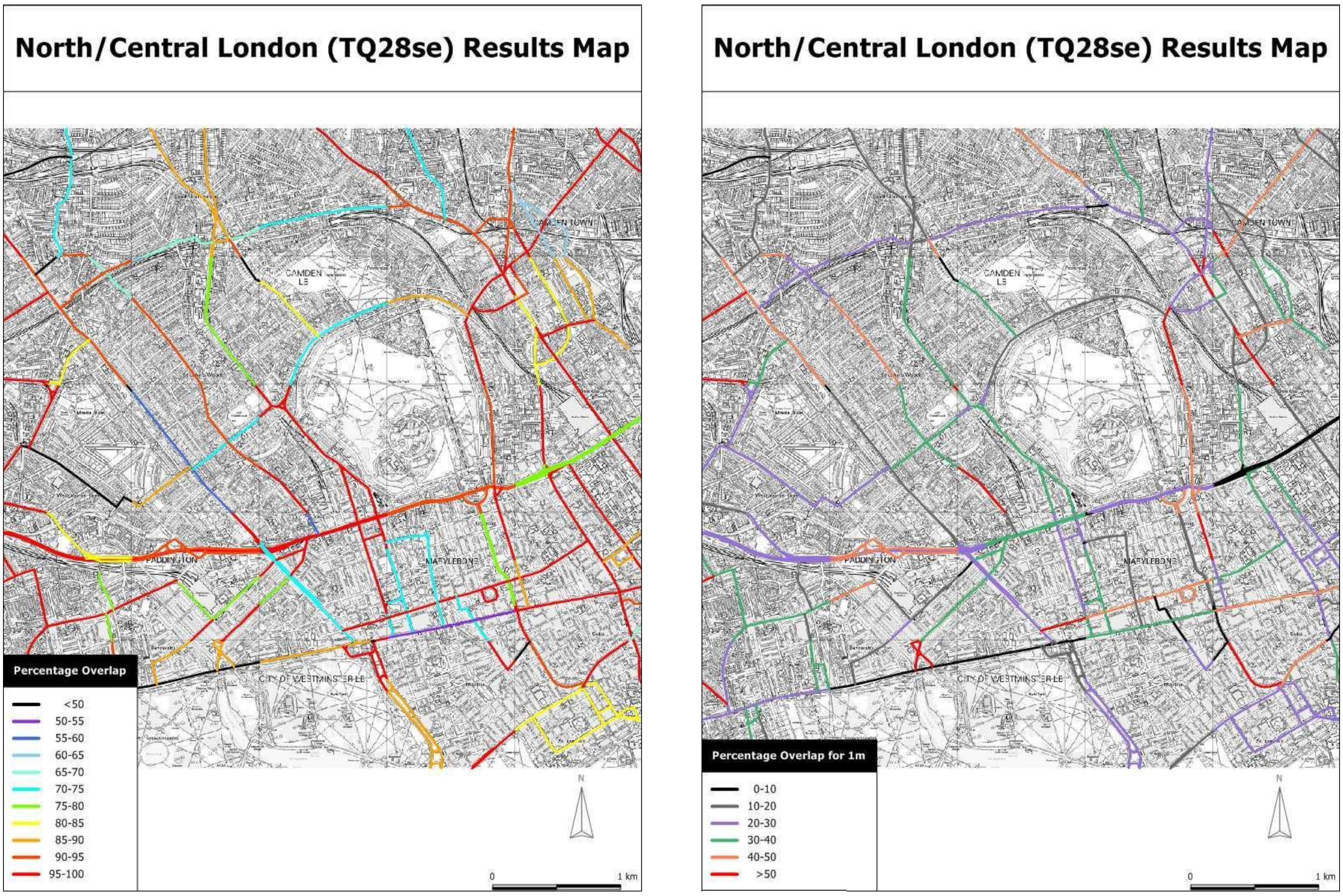


Figure 6-2: Evaluation of OpenStreetMap quality in London (source: Sofia Basiouka, 2009)

The main question that this research poses is whether the OSM data is good enough to be applied in cadastral projects. The concerns are various and the parameters that derive from the current research should be taken into consideration, meaning that the questions to be answered are numerous.

6.3. The first practical application

The first practical application took place at Kallithea municipality, close to the center of Athens, in a one-day application during the winter of 2012 (Basiouka & Potsiou, 2012a). Nine volunteers participated, seven blocks of buildings were traced, one handheld GPS and one iPad Mini were used. The handheld GPS was used only to prove that due to signal obstacles, the accuracy is not within the accepted values required by the mapping agency. The second approach adopted the online orthophoto viewing service provided by the NCMA S.A. The land parcels were drawn online on the LSO with the aid of the iPad. The cadastral extract of each land parcel contained an image with the property's polygon and its coordinates in HGRS 87. The first technical approach adopted the main lessons of the governmental crowdsourced case studies that were presented previously. The second technical approach was adopted to serve the national reality. The whole process is divided into four main steps: brief training of the volunteers in the field, spatial data collection with handheld GPS, repetition of the process and digitization of the parcels on the web-mapping tool provided by the official mapping agency, and evaluation of the results at the laboratory afterwards by the research team. The workflow is given in the chart to the right [Figure 6.3]. The main reason that all evaluations of the four practical experiments were carried out at the laboratory afterwards is based on the nature of the research, and its innovate approach, which mean that the results have to be evaluated by the research team for the first time.

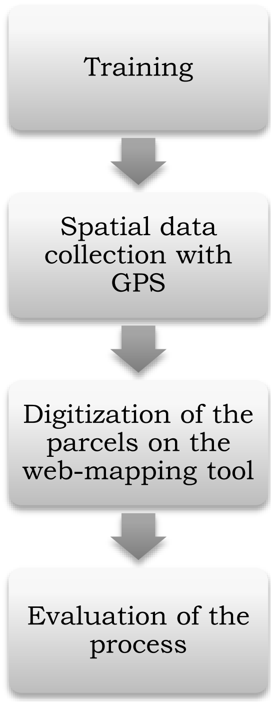


Figure 6-3: The process of the first experiment

Young students, all under 25, who were familiar to new technologies took part in the experiment. All were local residents and property owners in the areas of interest, a selection based on the perception that no one knows the local area better than its residents. The idea to recruit young participants was adopted from the main lessons of the previously explored case studies.

6.3.1. The area of interest

The first urban experiment was carried out in the city of Athens in the municipality of Kallithea, which stretches between Athens and Faliro Bay. Kallithea (meaning "the best view") is the 8th largest municipality in Greece (100,641 inhabitants, according to the 2011 census) and the 4th biggest in the Athens urban area (following Athens itself, Piraeus and Peristeri). Additionally, it is the most densely populated municipality in Greece, with 21,192 inhabitants per km² in 2012 (Hellenic Statistical Authority, 2012) [Figure 6.4].

The center of Kallithea lies at a distance of 3 km to the south of Athens city center and the north-east of the Piraeus city center, and extends from the Filopappou and Sikelia hills in the north to Phaleron Bay in the south; its two other sides consist of Syngrou Avenue to the east (border to the towns of Nea Smyrni and Palaio Faliro), and the Ilisos River to the west (border to the towns of Tavros and Moschato.

Figure 6-4: The area of interest

The site on which the city was developed covers the biggest part of the area to the south of Athens, protected in ancient times (5th century BC) by the Long Walls to the west and the Phalerum Wall to the east. The town and its citizens are mentioned among other places in Plato's Dialogs (Leriou & Mourouglou, 2006).

The area was selected for the implementation of the first practical experiment due to its location close to the city center, high-levels of attached building construction typical of urban areas in Greece and its magnitude, as it is one of the biggest municipalities. The first phase of the cadastral survey was concluded in this specific area by 2008 and the locals have submitted declarations of ownership in hard copy at the cadastral offices. Since then, due to blockages in the processes by the NCMA S.A., the procedures have only recently proceeded to the second phase of the cadastral survey.

6.3.2. The GPS approach

The GPS approach was only tested to prove that it is an incompatible methodology for urban areas in Greece. The experiment took place in an area characterized by construction and high blocks of buildings due to the building regulations. The volunteers were asked to collect GPS tracks of the blocks of buildings and the frontage of their block with the handheld GPS [Figure 6.5). The rear boundaries of each block could not be collected due to the attached construction system of parcels at the area of interest.

Thus, four edges were collected for each block and only the two front boundary points for each parcel. The measured points were depicted on orthophotos provided by the official mapping agency and give spatial analysis up to 20 cm in urban areas.

As was predicted, the results using the handheld GPS were disappointing compared to the technical specifications required by the official mapping agency.

Figure 6-5: The GPS that was used for the experiment

Due to signal obstacles, the results indicated divergence of between 5 to 8 meters from the real coordinates of the points. The results are presented in the map [Figure 6.6]. The red lines give the real boundaries of the blocks and the green lines show those that were measured with the handheld GPS. As an alternative option, the measured points could be moved to the actual position visually by the experts at the laboratory, however, the aim is to propose an alternative model which is simple not only in implementation but in the manipulation of the data as well.

Figure 6-6: The results of the GPS measurements

6.3.3. The web-mapping approach

Thus, within the same day, the experiment was repeated in an open area. The volunteers were provided with a Wi-Fi and cellular iPad Mini connected to the Internet and visited the web page of the national mapping agency where the web-mapping tool of the orthophotos is hosted. The orthophotos viewing service, which is provided by the system, creates a mosaic map. The orthophotos themselves were produced between 2007 and 2009. Their spatial analysis approaches 20 cm in urban areas and 50 cm in rural areas. After brief training the volunteers were asked to digitize the boundaries of their property with the aid of this web-mapping tool and interface. The young volunteers used it to create the interim cadastral map extract of their building [Figure 6.7]. The land parcels of their properties were drawn online and every extract was saved automatically. Each extract was accompanied by the parcel's coordinates and total area, which could be used comparatively in a further step of the process as a control. The extract offers researchers the opportunity to save the outline of each parcel in accordance with its coordinates so that it can be reproduced in any design software for manipulation and evaluation. The extract also offers the exact area measurement that can be tested with the real area that is given in official documents such as contracts. The only deficiency that was noted in this approach is not in terms of accuracy, but in terms of the result, which is not a unified seamless drawing. The extracts constitute records for each block and require connection. The figure left indicates the extract showing the marked parcel and its coordinates.

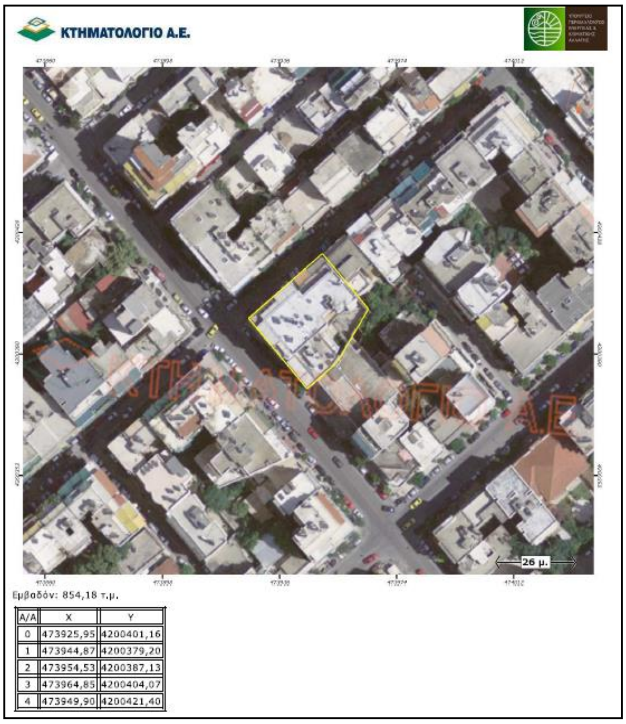


Figure 6-7: The extract of the viewing service

The figure below shows the digitized blocks of buildings, that coincide with the actual boundaries [Figure 6.8].

Figure 6-8: The results of the web-mapping approach

It is clear that concerns over accuracy can be easily bypassed with this specific methodology, which can produce sufficiently accurate, reliable and up-to-date results. The nature of the application also indicates the accuracy that it is required. In cadastral surveys especially, the accuracy varies depending on the stage of the process. For the creation of the interim cadastral maps, the accuracy can be lower. In urban areas for example, the required accuracy can be achieved by digitizing the land parcels on orthophotos provided by the national mapping agency. Digitization using orthophotos is in fact the same method used by cadastral surveyors.

6.3.4. Results of the first experiment

According to the research team's evaluation as well as the opinion of the participants, the whole process was straightforward and quick, offering the opportunity for local residents to conclude the process from data editing to map rendering. The young participants agreed with this perception, due to their familiarity with new technologies [Figure 6.9]. In terms of accuracy, the result satisfied the requirements of the official mapping agency. The methodology applied, therefore, offered a result that can be adopted by the NCMA S.A. and applied in urban areas as it is within its required technical specifications.

The participation was satisfactory and the time needed was eliminated dramatically without taking into account the reduced cost. The volunteers were willing to participate, answer questions and get involved in the experiment. Their involvement can be highlighted as a main component of the proposed model as it guarantees the process and helps to overcome the technical issues.

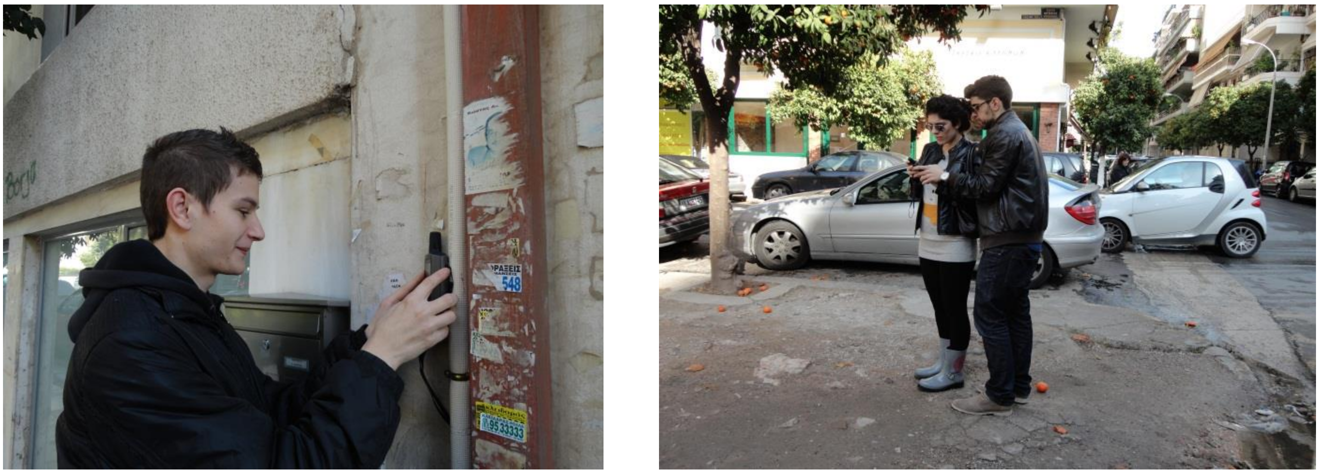


Figure 6-9: The volunteers that participated in the experiment

The first experiment resulted into two main conclusions: the required accuracy may not always be the highest possible depending on the experience of the team, however, the required accuracy can be met with the aid of the viewing service that is provided by the national mapping agency. The viewing service could also be used in an extensive application designed and launched by the national mapping agency. The application may be accessible via smartphones and computers and landowners may declare their ownership from a distance. For example, Mourafetis *et al.* (2014) have recently worked towards to this direction and they have launched a new approach in the cloud based on ESRI's ArcGIS online application named LADM. The research team used the orthophotos as a basemap and allowed citizens to use their GPS-enabled mobile phones to provide information about the location of their properties. The research carried out in the city center of Athens and the results indicated that no gross errors are detected and the location accuracy depends on the type of mobile phone used and on the existing network of antennas.

This first experiment, as a forerunner, is promising as it combines the VGI philosophy with new technologies and from-a-distance manipulation of data. It is clear that the volunteers can be involved in the next steps of VGI such as uploading and editing data so that they can also produce the final map. Data manipulation can be further improved with the aid of databases that will also store attribute data. The next experiment investigates this direction.

6.4. The second practical application

The second practical application took place as an experiment with the aid of twenty undergraduate students of the School of Rural and Surveying Engineering, NTUA, who undertook the 9th semester module “Cadastral Systems Development and Management” (Basiouka & Potsiou, 2014). The experiment was designed to test if OSM can be used for cadastral purposes. Its aim was for volunteers to collect and store attribute and spatial data simultaneously and online. OSM can service this purpose and can offer general assistance in various land administration issues. The experiment was carried out in the historic city center of Athens [Figure 6.10] and the area was divided into two parts: the first part was enhanced with attribute data, while the second part with both spatial and attribute data. The first area is located in the eastern part of Acropolis Hill and north of the Acropolis Museum. The second area is south of the Acropolis and directly adjacent to the Acropolis Museum. It is remarkable that, before the experiment, the parcel of the Acropolis Museum lacked attribute and spatial information [Figure 6.11].

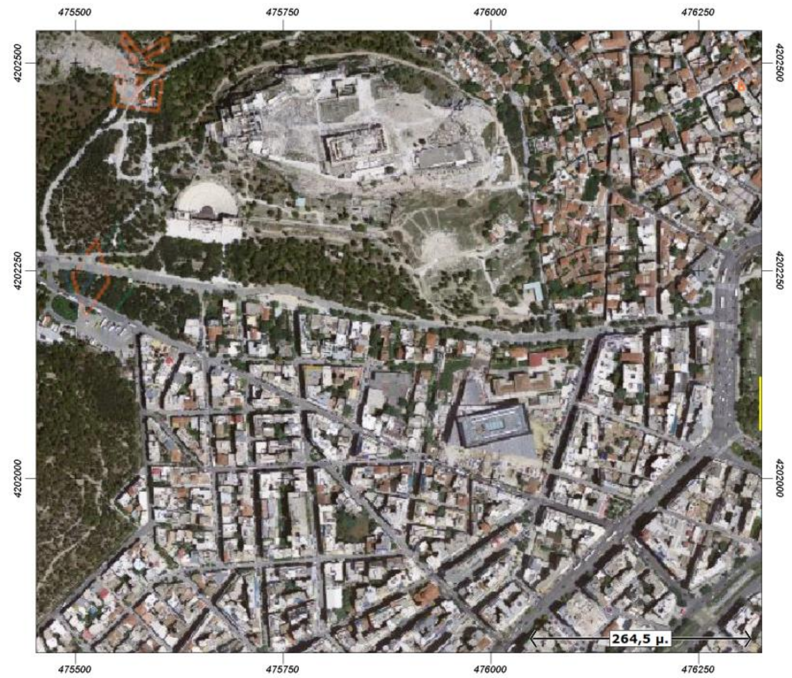


Figure 6-10: The area of interest (Source: NCMA S.A.)

The two areas were divided into blocks: each student edited two or three blocks of buildings depending on their size and students were left free to fill in the required information.

6.4.1. The area of interest

The area of Plaka is an historical neighborhood of Athens, in the heart of the city center and with cultural and historical significance. The settlement pattern consists of small, narrow paths and blind alleys, small houses that do not exceed two floors and small private yards. Its land use is restricted to general residence with small shops that cover the needs of local inhabitants and small touristic shops and cafes or restaurants for visitors. According to the Ministry of Finance, the land value per square meter fluctuates between 1550 and 3000 euro.

The neighborhood of Plaka is protected by Greek legislation and UNESCO with a series of laws regarding the protection and maintenance of its unique physiognomy. A series of laws regulate its architecture, protect the monuments that are located within it and regulate the land uses in the wider area according to its archaeological importance. The Greek state has enacted presidential decrees for all the manifestations that rule the area of interest. It is remarkable that there are more than thirty single legislations concerning the specific area, underlying its significance and the necessity of holistic protection. Six single laws protect the area archaeologically. The first was established in 1929 (Government Gazette A', 240/23-07-1929) and it has been modified five times since then. The protected area has been extended and the last law outlined the boundaries of the protected area by naming the roads that enclose it (Government Gazette D', 96/10-02-2004). Four laws give the rules for urban planning and one law concerns land use (Government Gazette D', 1329/07-10-1993). More specifically, the area can only be used for general housing, with small coffee shops, restaurants and shops that serve the neighborhood's needs. Shopping centers, industrial units or any other human activity that may destroy the area is strictly prohibited.

Figure 6-11: The area of interest before the experiment (Source: OSM)

6.4.2. The OSM approach

The practical application is divided into five main steps: training, research into legislation and planning restrictions, autopsy, data collection and manipulation, evaluation of the process. After brief training the students were left free to adopt the desired methodology and approach the case study according to the requirements posed by the research team. The students were asked to contact or visit the responsible public services and collect information about the urban

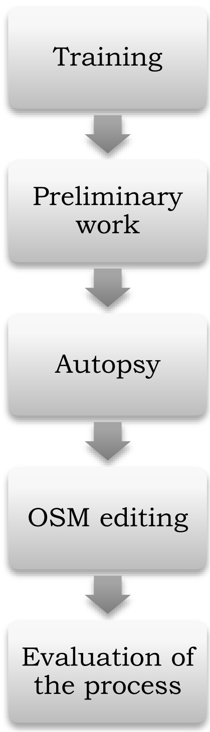


Figure 6-12: The workflow of the experiment

planning regulations, the permitted uses of buildings and the archaeological restrictions of the area as a second step of the process. The students collected general information important for attribute data enhancement within OSM. The information was irrelevant to the cadastre but correlated to related land administration issues. Their incorporation within OSM could broaden the horizons for similar experiments. The third step was focused on the research that the students did in the area. The students visited the area and collected attribute and spatial data with the aid of paper maps, collected GPS tracks by using handheld GPS or smartphones and enhanced their field research with photographs. The students created an account on OSM and edited the attribute and spatial data. The attribute data was edited according to the categories that already exist on OSM and the spatial data was enhanced based on the three different methodologies OSM offers to its users. At the end of the experiment, the students evaluated the process and identified the perspectives and the concerns [Figure 6.12].

The team estimated that the time required for the whole process was less than a week including the time needed for familiarization with the OSM editing process and the required contact with the corresponding public services. The cost remained low except for the GPS provided to them and/or the smartphone equipment, which was optional for those who already had one.

6.4.3. The attribute data collection

The attribute data collection is based on two main categories: general data about the area of interest and particular data about each building and floor.

Figure 6-13: Attribute data editing within the OSM environment (source: OSM)

The students were asked to edit the names of roads and complete the missing information, add the most predominant POIs such as monuments and add the condition, use and number of floors for each building.

All the information was stored within the OSM in the given categories [Figure 6.13]. OSM offers flexibility to its users to edit the data by using four different editors: iD, Potlach2, Josm or Merkaartor. The first two editors are incorporated within the program. The last two are external, require plug-ins and although they are considered as more complex in use, they offer greater flexibility and advanced functionality. For the specific task, all students used iD editing as it filled the requirements and the needs of the research and was evaluated as easy and quick.

Although the system is open and flexible in its use, a set of rules were posed so that the representation would be unique and all students would follow the same guidelines. First, the annotation of the roads had to follow particular rules for a unique presentation. Thus students were advised not to use Greek letters or caps lock. Figure 6.13 shows that not all students followed the specific advice. Secondly, the condition of the buildings was divided into four main categories: intolerable, deficient, fair and good.

Figure 6-14: The OSM before the attribute data enhancement (left) and after it (right) (source: OSM)

The researcher set out the rules so that all students would use the given terminology in the same way. The term "intolerable" was given to ruins. The term "deficient" was given to buildings that require extended renovation and the term "fair" was given to those that require little renovation. Thirdly, another issue that the research team faced had to do with the land use type, which differentiated on each floor. A general standard was proposed: the predominant use of the building was recorded and the POIs were shown by pins, creating a temporally accurate thematic map [Figure 6.15]. The practical application indicated that the existing land use matches the permissible land use.

Figure 6-15: Digitization of the parcels on the OSM (source: OSM)

6.4.4. The spatial data collection

OSM offers users the flexibility to either collect spatial data with their equipment and upload it or digitize the buildings on the satellite layer of the map using the tools provided and the desired editor. The students were asked to follow the methodology that they preferred and to document their choice accordingly. The result was extremely interesting for the research team. The majority of the students selected the easy way to digitize the satellite image from Bing by using one of the two editors and underlined the loss of accuracy due to the angle of the image [Figure 6.15]. A small percentage of the students tried to collect GPS tracks with their GPS or smartphones but they mentioned the signal discrepancies that also affected the accuracy as a major disadvantage. A great number of students however used their knowledge of commercial GIS packages and created a semi-hybrid model using both ArcGIS and OSM. They used the orthophotos provided by the national mapping agency, then they digitized the buildings and created a new layer. The new layer was imported into OSM by using the Potlach2 editor [Figure 6.16].

The results of the last approach were impressive as they combined two different methodologies; it offered really accurate results in terms of quality and supported the desired model of experts and volunteers simultaneously. Moreover, OSM offered the capacity to identify the boundaries of the land parcels by using photo-interpretation methods and by digitizing the satellite images, which is useful and easy especially in urban areas like this where building construction hinders field measurements [Figure 6.17].

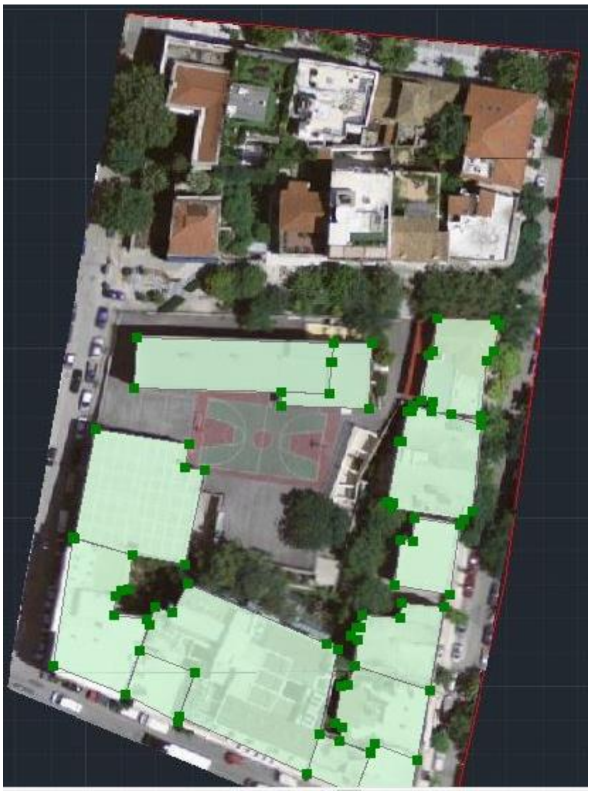


Figure 6-16: Editing with the aid of ArcGIS & OSM.

In general, the experiment indicated that students' knowledge about the objective was crucial for its success. Errors such as roads that crossed buildings or other common topological issues were either avoided or corrected in due time.

6.4.5. Results

Following the completion of the application, the students were asked to evaluate the process and the software that they had used, and the research team also evaluated the results. In most cases, the evaluation was identical.

Strengths of the experiment:

- Quick and inexpensive methodology.
- Easy to use/capture/edit/store data.
- Open to the public to participate and gain knowledge.
- Flexible in terms of editing and manipulation by non-experts.
- Accurate interim maps.
- Online and real-time monitoring of the work.
- Applicable in a variety of contexts.

Concerns over the experiment:

- Malpractice of third parties, which may lead to changes or damage to the work.
- Limitations or generalizations within the attribute data storage.
- Quality concerns, which may be bypassed.

It is clear that the crowdsourcing techniques may be extremely useful when the borders and the rules are well defined from the beginning. The experience has indicated that well structured projects, which put citizens at the center of the decisions and adopt crowdsourcing techniques may flourish with the support of experts and governmental bodies. The specific practical experiment indicated the great potential that OSM may offer in cadastral procedures as a significant part of LAS that may be applied with minor differentiations or improvements in various land-related projects. OSM may be used for various projects in areas where no accurate basemaps exist.

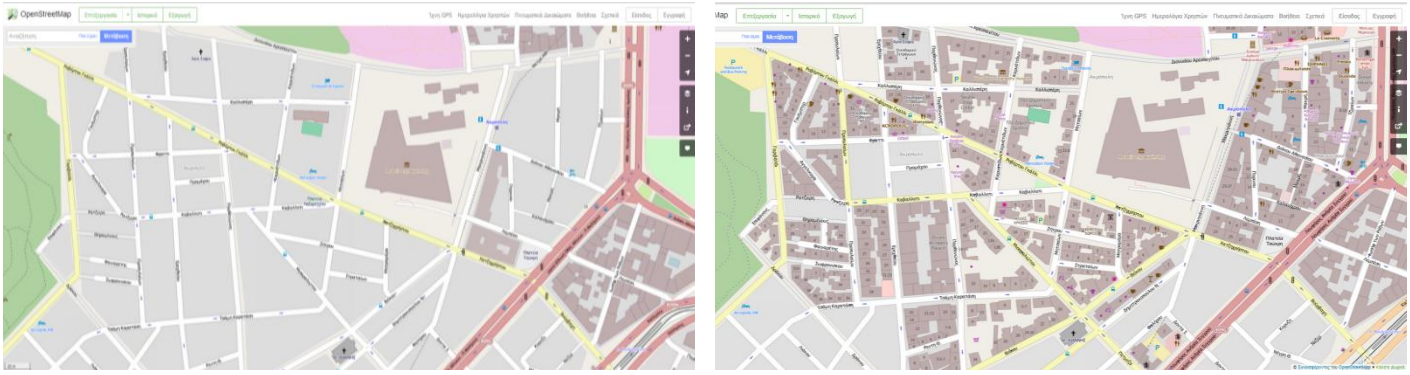


Figure 6-17: OSM before the spatial data enhancement (left) and after it (right) (source: OSM).

This experiment constitutes the first application worldwide which explored the potential to introduce VGI in cadastral processes by using the first crowdsourced map, OSM. Its innovation is also focused on the involvement of undergraduate students for the accomplishment of the specific purpose. It is a general fact that VGI and LAS are two different academic fields that attract the interest of the academic team due to their socio-economic impact. Their combination is a challenge that has many aspects still to be explored.

6.5. Concluding remarks

The sixth chapter investigated the first two different practical experiments in urban areas with the participation of young people, undergraduate students of the SRSE and landowners. The two practical case studies indicated that the use of online web tools and dynamic maps have a great potential for data collection, editing and storage. In terms of technical editing, the process is simplified. The main innovation is focused on the potential of use from a distance, which means it can be supported by owners who live abroad and can submit their declaration with spatial documentation online and not in hard copy format.

The strengths of both experiments can be summarized in five main categories. Both supported an inexpensive and relatively quick methodology with web tools and open data that is easily manipulated with the aid of the new technologies. The cost of data is limited to data storage (in the first experiment) or completely without cost (in the second experiment) where OSM is also used for data manipulation and storage. Moreover, both case studies provide an easy-to-use methodology, which only required a short training period and supervision by the research team, and flourishes with the aid and active participation of undergraduate students. Their participation can be formally extended in larger projects and supported with contributory benefits such as scholarships and gaining experience, as the international experience in relevant projects has revealed. The most significant case study is Community Mapping for Exposure, which was launched in Indonesia, as the OSM platform was utilized and the young students/volunteers were rewarded for their services. Finally, participation from a distance can assist in data collection with limited fieldwork, which need only be done for the collection of reference points and evaluation of the result of the maps.

Table 6.2 indicates the predominant results of the survey.

➢ Web tools and dynamic maps such as OSM can play a significant role in cadastral survey in data collection. Fieldwork can either be totally replaced or reduced to data evaluation by the official mapping agency in urban areas.
➢ The participation of young people facilitates the manipulation of new technologies and the recruitment of undergraduate students of the SRSE or Geography simplifies and accelerates the procedure. The students can play a vital role in the training stage and in data collection and manipulation as team leaders and data registers.
➢ The cost can easily be kept low as the data collection, editing and storage are incorporated into one stage. The storage and maintenance of the data will be done by the national mapping agency in accordance with its evaluation.
➢ OSM offers the opportunity of real-time monitoring of the work supported by up-to-date databases and can offer technical assistance simultaneously.
➢ Among other positive remarks are the elimination of time, the flexibility and participation from a distance by landowners who may live abroad and can easily declare their ownership online.
➢ The two practical applications indicated that accuracy may vary depending on the required result and the vital role that orthophotos provided by the official mapping agency may play. Orthophotos can also be used in applications for data editing from a distance by landowners.
➢ Issues such as the malpractice of third parties or the limitations or generalizations within the attribute data storage that were faced in OSM use can be easily bypassed with minor software improvements by volunteers or the official partners of the project and a central offline back up by the official mapping agency.

Table 6-2: Concluding remarks of the sixth chapter

7. TESTING CROWDSOURCING TECHNIQUES IN RURAL AREAS

7.1. Introduction

The seventh chapter investigates two crowdsourced experiments that were carried out in a rural and in a semi-rural area, exploring an alternative process to the official cadastral survey. The seventh chapter concludes the practical application of the study and has a technical focus on handheld GPS, smartphones and Apps. It also focuses on landowners as volunteer participants in the experiments, with the aid of the researchers as team leaders and the implementation of workshops at the beginning of each experiment as vital parts for their success. The results of the two experiments were both evaluated by the research community at the laboratory afterwards.

The application area chosen for the third experiment is the rural part of the village Tsoukalades, on the Greek island of Lefkada, which for several reasons has been under cadastral survey for more than 12 years; so far the whole traditional cadastral survey procedure has been repeated four times due to a number of errors and disagreements between the landowners and the cadastral authorities. Fifteen volunteer landowners participated in a weekend experiment and collected geospatial data for the delineation of their land parcel boundaries on a cadastral map where the spatial data were collected with the aid of a handheld GPS after brief training. The outcome of the interviews with the landowners and the resulting citizens' cadastral map are presented. The citizens' cadastral map is compared to the cadastral maps compiled using traditional procedures by the private cadastral office responsible for the cadastral survey in the area and by the cadastral authorities. The results are given at the end of the experiment and indicated that 70% of the crowdsourced measurements that were collected in a weekend are within the requirements of the official mapping agency. The true boundaries were measured by the official mapping agency after three wasted efforts by the private contractor.

The last practical experiment was carried out in a semi-rural area close to Chania city, on Crete, where fourteen landowners participated voluntarily in data collection with the aid of an iPhone 4S and free-of-charge applications that were downloaded directly to the smartphone and service the measurement of points, distances and areas. For the first time, the collection of attribute data for the cadastral databases was approached with the aid of a mobile application designed by Imperial College. Both datasets were stored on the iPhone and were downloaded for manipulation afterwards. The area in Chania is one of the new areas that are about to be integrated into a formal urban plan. The area has been experiencing urbanization for the last 30 years and faces severe delays in land development. The results of the measurements of spatial data were compared to the actual boundaries as they have been designated on the official drawings, which although approved, have not yet been implemented.

While these experiments were carried out in Greece, similar experiments were also carried out worldwide only a couple of years later. Roberts *et al.* (2013), who carried out a similar experiment, investigated if neo-cadastral surveying on smartphones is feasible and answered negatively by underlining that the gap will be soon filled. They also refer to Dasgupta's (2012) research, which supports the idea that precise surveying will remain fundamental for boundary determination. Dasgupta suggests controversially that the differentiation between timely, imprecise information and high-quality but delayed information is under discussion within the different parties. However, another statement should be added in this perception, which is that a fit-for purpose result can address the increased needs of society for land development and the creation of interim cadastral maps as a first step to unblock the market.

Both experiments indicated a great willingness of landowners to participate, as they easily understood that an alternative solution to the problem that they face could come out of this process. The strongest incentive that motivated the landowners in both experiments was their need to unblock the market so that their land could be mortgaged.

The table indicates the main aims of the seventh chapter.

➢ Investigation of an alternative crowdsourced model for rural areas. The experiments focus on the creation of interim maps for cadastral purposes and aim to propose quick and inexpensive solutions to general land administration issues that require land surveys worldwide.
➢ Test of handheld GPS and smartphones as alternative solutions to the official procedures that require expensive equipment and field surveys.
➢ Recruitment of landowners as volunteers who have two important motivations: a wish to unblock the market and a better local knowledge than anyone else.
➢ Use of new technologies and applications in the experiments in two different areas that confront severe land administration problems.
➢ Investigation of volunteers' opinions with interviews. Their thoughts were written down and are presented in detail.
➢ Evaluation of the process afterwards at the laboratory.

Table 7-1: Predominant components of the seventh chapter

7.2. The third practical application

The third experiment was carried out on Lefkada island during a summer weekend of 2011 with the aid of fifteen landowners as volunteers, three team leaders who trained the citizens and one handheld GPS (Basiouka and Potsiou, 2012b). Nineteen land parcels were traced in an area of interest, which is a rural one with olive trees and cultivated areas. The parcels were chosen randomly so that the sample would be representative and the landowners volunteered to collect the tracks of their boundaries with the aid of a handheld GPS. The aim of the experiment is to introduce a process that can serve general land administration issues and required field surveys.

7.2.1. The area of interest

Lefkada is an island of the Ionian Sea and belongs to the Ionian islands complex. It lies between the islands of Corfu and Kefalonia. It is very close to the shores of western mainland of Greece covering an area of 302.5 square kilometers and is the fourth in size in the Ionian islands complex, with a population of 23,000 people (Domi, 2005a).

The community of Tsoukalades is one among seven communities that are part of the municipality of Lefkada. Tsoukalades village is located at 220 meters elevation in the northwest part of the island and it had 431 habitants according to the last census. However this record varies depending on the season of the year [Figure 7.1].

Figure 7-1: The area of interest

7.2.2. The official process

The compilation of the cadastral survey began at the community of Tsoukalades [Figure 7.2] during the first phase of cadastral surveys and it is still incomplete due to errors and discrepancies between the existing properties and the cadastral maps produced by the contractor responsible for the cadastral survey, despite his efforts to re-survey the area. The main errors, according to the mapping agency, are noticed in the location, shape and boundaries of the land parcels. Errors are also noticed in the records of the cadastral tables where properties are recorded as belonging to "unknown owners". In an effort to unblock the market, NCMA S.A. tried to identify the size of the problem and to do that its qualified staff re-surveyed the boundaries of the parcels in two cadastral units, 340370913 and 340370914, during the summer of 2009 (Papadopoulou, 2010). The process has been implemented in cooperation with NCMA S.A. and the municipality of Lefkada and the new cadastral maps and records compared to those provided by the contractor.

The owners were asked to indicate the boundaries of their parcels during the re-survey and interim sketches were designed by the NCMA S.A. experts during the field measurements. The authorities recorded the owners' and/or witness' name. New digital cadastral diagrams were compiled on large scale orthophotos (LSO) produced in 2007 by NCMA S.A. as cartographic basemaps. A new correction process was adopted. All records were checked and compared to the new spatial data.

Figure 7-2: Cadastral survey produced by the contractor (in red); cadastral survey produced by NCMA S.A. (in green).

The obvious errors were corrected administratively, with a decision by the head of the cadastral office, and all individual cases were checked no matter whether the parcels were declared by the owners or were located after the correction. Figure 7.2 shows a part of the cadastral map created by the contractor (in red) and the new survey by NCMA S.A. (in green); large discrepancies in location, shape and size of parcels can be identified which mean that gross errors had been made during the first cadastral survey.

The final cadastral diagrams and tables have not been formed yet. The next steps of the re-survey process followed by NCMA S.A. are that:

- Cadastral tables and diagrams will be suspended at the cadastral office and the municipality office of Lefkada at a scale of 1:1500 on the LSO.
- Extracts from the cadastral registrations will be sent by postal mail to those who have declared a right. Through the suspension procedure the rights holders will be able to check the content of the registrations and either accept the new boundary survey with attestation of their original signature or submit objections regarding any errors or oversights.
- Detailed information is attached to each letter, which will be sent to the interested parties explaining the process that they should follow, and the actions completed to date.

- The whole process will be open to anyone with an interest so that he/she will be able to submit an objection. The coordinates of each parcel will be made public so that the accuracy of the cadastral extracts can be tested.

- Announcements will be posted at the communal office of Tsoukalades so that all interested parties will be informed under the responsibility of the municipality of Lefkada.

7.2.3. The various types of errors identified by NCMA S.A. on the contractor's cadastral survey

According to the NCMA S.A., after the re-survey of cadastral units 340370913 and 340370914, six error categories were identified on the cadastral survey and the cadastral diagrams delivered by the contractor. The various final cadastral extracts (after the re-survey by NCMA S.A.) sent to the landowners by NCMA S.A. for verification and objection submission included:

- Land parcels which have been redefined into the same cadastral unit after the boundary or location correction.

- Land parcels, which despite being declared by the owners within the declaration period, were not recorded by the contractor on the interim cadastral plans. The follow-up research proved that they should be registered in the cadastral records.

- Land parcels registered on the interim cadastral plans by the contractor as belonging to the incorrect cadastral units but after the re-survey it was found that they should be relocated within cadastral units 340370913 and 340370914.

- Land parcels which had to be removed from cadastral units 340370913 and 340370914 as after the re-survey it was discovered that they belong to other units.

- Land parcels that were not registered in the cadastral records at all. They were indicated during the re-survey by NCMA S.A. and defined to be within cadastral units 340370913 and 340370914. However, the specific parcels cannot be legally registered to their owners now within this process due to legislation restrictions.

- Land parcels which are located in adjacent cadastral units and are affected geometrically due to the correction of the boundaries of the unit under re-survey.

7.2.4. The practical crowdsourcing experiment

Figure 7-3: The experiment process

Volunteer landowners mapped the northwestern part of the area of interest (with the unique cadastral code 340370914) during a weekend. Nineteen parcels were traced with the aid of a handheld GPS, and fifteen volunteers and three experts from the NTUA research team participated in the project. The idea was adopted from the weekend mapping parties, which are organized in the United Kingdom for cartographic purposes (Basiouka, 2009). The parcels were chosen randomly so the surveyed sample will be representative. Not all the parcels of the area were mapped because not all the interested parties were present on the island of Lefkada or were available to participate when the experiment took place. The volunteers that participated were encouraged to show the boundaries of their ownership and collect the tracks themselves using a handheld GPS provided by the SRSE. The research team contacted the local authorities; the local authorities informed the landowners and asked for volunteers; a meeting was arranged between the research team and the volunteers to explain the objectives of this research and the use of handheld GPS; data were collected by the volunteers; interviews and discussion was arranged after the data collection; final data editing was done by the research team in the office. A flowchart showing the process of the experiment is given by Figure 7.3.

The adopted methodology was absolute kinematic positioning which is primarily used for navigation [Figure 7.4]. This method is appropriate for determining the position of boundaries by walking around their perimeter (Pacione, 1999). Its first advantage is that the data are collected in a relatively short time. There is no risk of gross errors (such as location of a parcel in a neighboring cadastral unit) as the landowners know the place well. In fact, nobody knows the area better than the landowners, who live and work there. Moreover only a single, low-cost GPS device is needed. Its main disadvantage is that the accuracy of handheld GPS devices is

Figure 7-4: The handheld GPS

influenced by several factors and varies with the location and the terrain where it is being used. The accuracy of GPS is also dependent on the signal strength. Many different environmental factors can further affect the accuracy of the GPS receiver, including atmospheric conditions, which can degrade the accuracy of the GPS unit. A good estimate usually varies between 5 and 10 meters. Moreover, kinematic positioning is vulnerable to multipath and obstructions to satellite signal, especially in the area of interest, which was an olive grove.

Figure 7-5: Volunteer landowners doing the cadastral survey

What made the volunteers participate to this experiment? The question is quite simplistic but the answer is clear. As Kingsley (2007) has noted, civil society shares the same goals and has created a non-hierarchical network of self-organized individuals. The interview with the volunteers showed that this specific network of volunteers was willing to participate so that the time and cost of cadastral surveys could be minimized and the errors eliminated; as they have experienced the disadvantages of the formal cadastral procedure at first hand, they themselves have pointed out that the procedures should be simplified, costs should be reduced and finally the real estate market should start operating again.

The identified strengths of the experiment are:

- Participation in the project was notable given the magnitude of the village, especially taking into account that the experiment was undertaken during the summer period in hot weather conditions [Figure 7.5.].

- The volunteers were extremely willing to participate in the project due to the inconvenience they had experienced from the formal cadastral survey (e.g. the high cost of preparing and submitting objections in order to correct the numerous errors of the cadastral survey prepared by the contractor; the fact that the property market was blocked for 12 years, etc.); they also answered sensitive personal information concerning their property.

➢ No boundary disputes among the owners were noted. Although a few owners were not present at the area of interest when the experiment took place, relatives or neighbors offered to show the boundaries of those properties, which were the actual ones according to the last cadastral extract provided by the NCMA S.A. agency. This is a good sign that landowners are indeed reliable citizens and can be trusted to collect such spatial/ cadastral information. Further, if VGI is formally introduced into the cadastral procedure, normally all landowners will be informed and engaged, so multiple measurements of the boundary points will be acquired; this will take care of any errors.

The identified weaknesses of the experiment are:

➢ Accessibility was limited at some points due to spikes or cultivated crofts. Due to the olive trees the GPS signal was obstructed in a few cases.

➢ Some older volunteers provided with a handheld GPS were not familiar with new technologies, preferring to keep a supervising role by indicating the boundaries of their parcels to the younger volunteers.

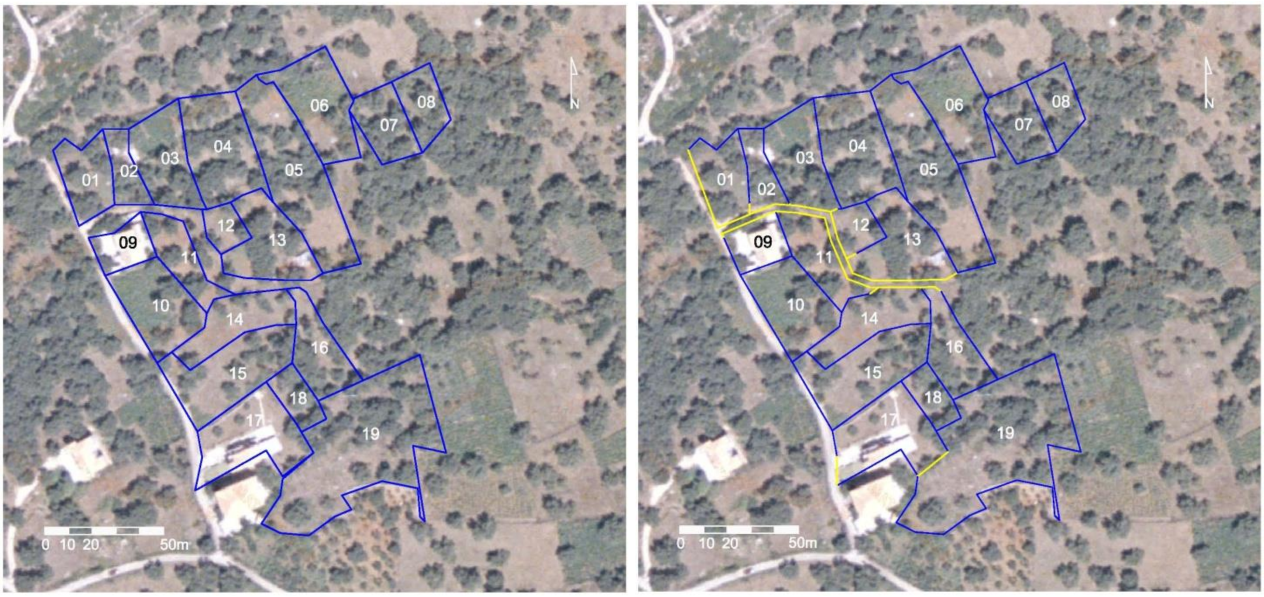


Figure 7-6: Left: Cadastral survey as compiled by the measurements of the landowners (in blue). Right: Cadastral map compiled by the measurements of the landowners after editing the obvious errors (in yellow).

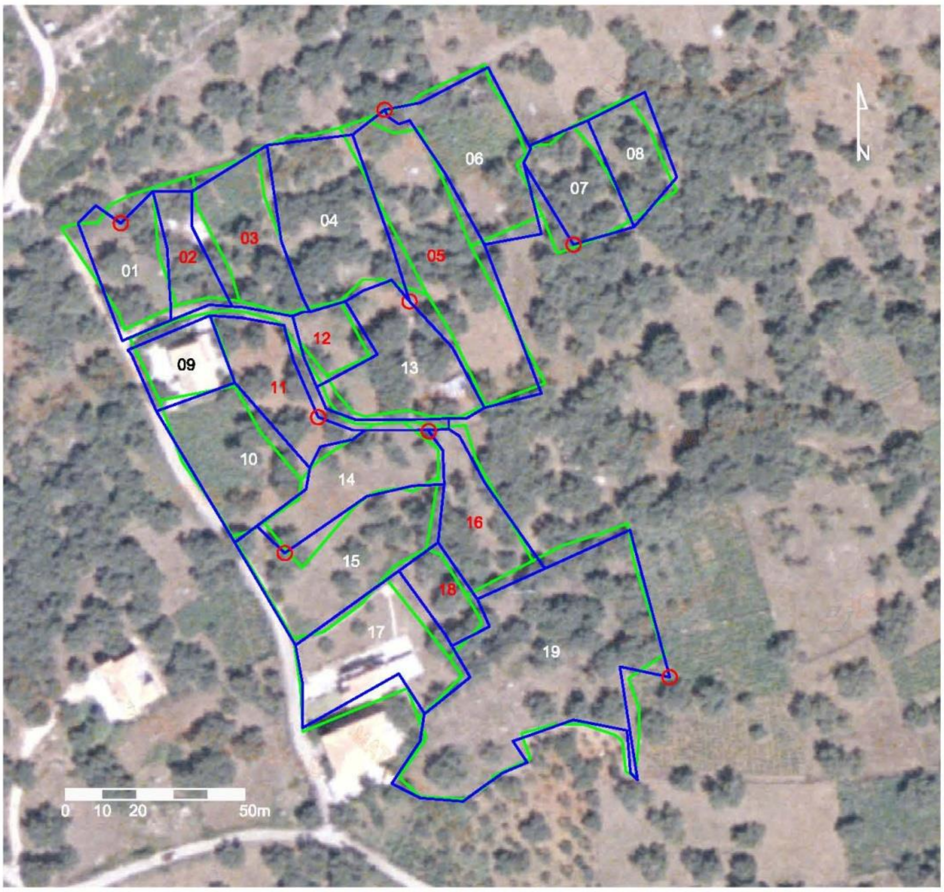


Figure 7-7: Cadastral re-survey provided by NCMA S.A. (in green) compared to the landowners cadastral survey (in blue)

The researchers edited the tracks and created the cadastral extracts at the laboratory afterwards. The GPS points were exported by the handheld GPS during the experiment and were imported by the research team into a drawing package. Each corner was shown as a node and each segment of the land parcels was traced by connecting the nodes; a simple procedure was carried out based on an interim sketch made in the field.

Figure 7.6 (left) shows an overlay of the cadastral map as it is derived from the field measurements made by the landowners, without any correction or adjustment, on the LSO. Obviously due to errors in the coordinates of the parcel boundaries, the width of a small path (of fixed width in the field) varied along the path on the map; in order to fix that an adjustment to both sides of the path was made locally. The smallest width (as it appeared along the path) was selected and the boundary lines were adjusted accordingly so that the path has a fixed width along its length and is located in-between the boundary lines as these were originally mapped by the owners. Figure 7.6 (right) shows the result of the adjustment of the obvious errors; the new boundary lines are marked in yellow. In any case, the final result is derived by editing the measurements taken by the landowners, without using any other source of information.

The comparison [Figure 7.7] of the cadastral survey produced from measurements taken by the volunteers [Figure 7.6 right] to the cadastral re-survey provided by NCMA S.A. [Figure 7.2], which is considered to be the accurate cadastral map, shows as expected some discrepancies at the boundary nodes and the boundary lines of the parcels. More specifically eight of the hundred measured nodes (in total) have coordinate deviations greater than 5m (these nodes are marked in a red circle in Figure 7.7); the area size of seven out of the nineteen land parcels (37%) differs from the correct size (as on the NCMA S.A. re-survey), more than the acceptable tolerance in the technical specifications of the Hellenic Cadastre (these parcels are marked with a red cadastral code number in Figure 7.7). However, the location and shape of all land parcels are correctly defined and the area size of the majority of the land parcels is sufficiently defined (within the requirements). In contrast to the cadastral survey delivered by the contractor, where high accuracy surveying instruments were used and the formal procedures specified in the technical specifications of NCMA S.A. had been followed, almost all the land parcels were incorrectly shaped and the area size of only 10.5% was within the technical specification requirements.

7.2.5. The volunteers' interviews – the odyssey of their property registration

During the second day of the experiment, all volunteers participated in a meeting and were interviewed about the process of the formal cadastral survey in their community [Figure 7.8]. Based on the volunteers' interviews the greater area was re-surveyed more than four times.

The first cadastral map version was done at the island's cadastral office where the landowners were asked to define the boundaries of their land parcels on 1:5000 orthophotos for the compilation of the cadastral maps. The result was not successful as trees cover the rural area so the exact boundaries and location of the parcels was ambiguous and visual recognition was difficult. The contractor then attempted a re-survey in the field with the aid of a handheld GPS, but without the involvement of the landowners, as the specifications did not require landowners' involvement in the field surveying. The result led to a general misplacement of several parcels within the same cadastral unit or in different cadastral units and even in different communities. The contractor tried to improve the situation without any significant results and the cadastral study was delivered to NCMA S.A.

Due to the increased number of remaining objections, once again surveyors went into the field as members of joint committees of the Hellenic Mapping and Cadastre Organization (HEMCO), the supervising agency, and NCMA S.A., the agency responsible for the cadastral survey, to investigate the number of errors claimed by the owners and to estimate the size of the problem.

NCMA S.A. then commissioned a complementary cadastral survey study and the area was surveyed by a new private contractor with the aid of total stations and GPS, according to the technical specifications, who however undertook to correct the errors in only some scattered areas within the greater area.

As a great number of errors still exist the cadastral survey cannot yet be finalized and, as a result, the real estate market has been blocked in the greater area for more than 12 years. To overcome the problem the new management of NCMA S.A. decided to fully re-survey the two cadastral units (those under study in this paper) in order to investigate the most appropriate procedure (within the existing legal framework and the technical specifications of the project), times and costs for a total re-survey of the area; the cadastral maps of these two cadastral units are still at the suspension stage open to the submission of objections.

Figure 7-8: Interview with some members of the team of volunteers

The volunteers were also interviewed about the major problems they had faced during the whole process of the formal cadastral survey [Figure 7.8].

Among all, the most important ones, according to the landowners' views, are:

- The cost of the whole cadastral survey process is extremely high. The owners are led to pay private lawyers and surveyors more than 2000€ to prepare the request for correction of their declared ownership each time they submit an objection. The specific amount is given for each parcel separately, on top of the fixed cadastral survey fee that has to be paid by each rights holder when an area is declared to be under cadastral survey.
- The long duration of the whole process has led to great discomfort for the owners.
- For more than 12 years the owners have been unable to transfer their properties as the region is still under cadastral survey and the boundaries or the location of their parcels are not fixed, although they are obliged to pay all property taxes for it.

7.2.6. Results

The first approach to using crowdsourcing techniques in the compilation of cadastral maps in rural areas shows that owners are willing to participate. The formal procedure, which requires that owners identify their parcels on orthophotos at the cadastral office, seems to be difficult and confusing to most of them. The results of the formal procedure can be so confusing that the whole cadastral survey can be delayed for decades, costs can be increased and the economic impact on the landowners, the tax payers and the market can be huge. On the contrary it is easy and cheaper for the owners to collect raw measurements in the field by themselves after brief training. No gross errors in the location of parcels have been detected during this experiment. Currently, it can be said that VGI can be implemented and integrated to cadastral surveys in a practical way, although there are still concerns. The first practical approach in rural areas was positive but more detailed research is still required.

The involvement of volunteers in the data collection and editing process [Figure 7.9] for the compilation of the interim cadastral maps should be further investigated in rural areas where there are no addresses and the visual recognition of land parcels on orthophotos is difficult for the landowners both in Greece and in other countries under cadastral survey.

The participants' motivations were recorded as being far away from altruistic, as Laarakker *et al.* (2011) first mentioned. The volunteers underlined the necessity for an updated LAS, which will guarantee their ownership, and were found to be extremely skeptical about the long period during which the cadastral survey has been stalled in their area.

In conclusion, the volunteers underlined many of the statements that were posed theoretically at the design stage of the general cadastral model: landowners are willing to participate in the editing of the collected data, as supported by the real meaning of voluntarism; and there is a need to identify a new role for the local authorities that may facilitate the cadastral survey by providing volunteers with open software and equipment but also by facilitating some brief training of the team leader. According to these statements, registration fees should be reduced as the landowners will actively participate in the cadastral survey, gross errors and objections will be eliminated and the duration of the survey will be reduced dramatically.

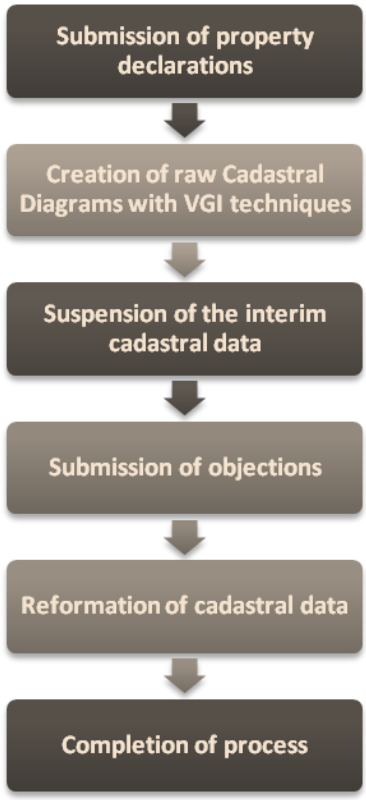


Figure 7-9: Proposed procedure for future cadastral surveys in rural areas

7.3. The fourth practical application

The last practical application was carried out in a district of Chania city, on the island of Crete, with the participation of landowners as volunteers in data manipulation and the use of smartphones for land administration purposes (Basiouka, 2014). The philosophy of the experiment was close to the previous applications, however, the methodology was very different. The research aimed to incorporate in one step the collection and editing of attribute and spatial data, which is officially divided into two separate procedures. Fourteen landowners participated voluntarily in data manipulation, one smartphone was used for data collection and storage and free-of-charge applications were selected for implementation in this specific context. Seventeen land parcels were traced in total and the process lasted three days including the training process. Although issues of privacy are out of the scope of this research, for the first time volunteers were asked to complete forms with personal data to simulate the submission of attribute data. The experiment investigates the use of smartphones and new technologies and explores the potential of citizens' participation in official procedures and in their simplification.

7.3.1. The area of interest

The city of Chania is located in the northeast part of the Prefecture of Chania. Chania is the second largest city of Crete and it lies along the north coast of the island, about 70 km west of Rethymno and 145 km west of Heraklion. The official population of the city is 53,910 inhabitants while the municipality has 108,642 inhabitants, according to the last census, and it extends to 2376km^2 (Domi, 2005b). The city of Chania can be divided into two parts: the old town and the larger, modern city. The city has seven districts. The practical experiment was carried out in a part of the district called Eleftheriou Venizelou, in the area of Koumpes, which belongs to the modern part of the city and is a semi-urban and semi-rural area [Figure 7.10]. The area has been under an urban regeneration process since 1983.

Figure 7-10: The area of interest

7.3.2. The urban regeneration procedure

"Spatial and urban planning in Greece is a fundamental tool for decision making to define strategy for land development and to secure economic growth, social stability, environmental protection and quality of life" according to Potsiou & Müller (2008). However, the design drawings, which forecast the creation of roads and siting communal facilities, have been under implementation for the last 30 years.

Urban land development in Greece was first ruled by the Housing Law enacted in 1923, according to which urbanization of new areas was made in two steps, the compilation of an urban planning study and a sporadic implementation of this study, according to the interest of the individual owners or the municipality. The Law presented great injustice in its treatment of the landowners and did not provide a unique development of the areas, so it was replaced by Laws 1337/1983 (Government Gazette A', 33/14-03-1983) and 2508/1997 (Government Gazette A', 124/13-06-1997) and their amendments. Potsiou *et al.* (2008) did thorough research on the process and the steps that should be followed. Thus, the procedure follows the steps below:

- Compilation of the General Urban Plan study (at a scale of 1:10,000), which defines the location, size and boundaries of all areas dedicated for urban development.

- Compilation of the detailed Urban Plan study, which refers to a formal set of rules and plans to define the zoning and building regulations to be applied on both private plots and the plots selected for common use and common benefit activities.

Figure 7-11: General urban plan of the area

- Ratification of the Urban Plan by a Presidential Decree.

- Compilation of the Urban Planning Implementation Act for each of the above areas. This study refers first to the compilation of the necessary cadastral surveys and the adjudication of current owners, due to a lack of cadastral maps in Greece.

- Ratification of the Urban Planning Implementation Act by a Prefect's Decision.

Urbanization in the area of interest is currently at the last step of the ratification of the urban planning implementation. However, the cost of the roads to be created, the construction of buildings for common benefit activities and the configuration of areas for common use financially burdens municipalities which have limited financial resources, especially contemporarily [Figure 7.11]. The cadastral survey, which is a national project, has already been completed without any difficulties in the area of interest and the cadastral office has been in operation since 2006.

7.3.3. The technology used for the experiment: smartphones & Apps

The idea to test smartphones for data collection and storage in the last experiment was inevitable due to the expansion of smartphones, their penetration in the population and the approval that they have gained from citizens. The first ever attempt to build a smartphone was helped by IBM who introduced Simon at the COMDEX Show in 1992. The device was able to make and receive calls, send emails and faxes and it had a touch screen. In the late 1990s many manufacturers such as Palm Inc. introduced PDAs (personal digital assistants), which had limited capabilities of desktop applications such as word processing.

In 2007, Apple introduced the iPhone and the history of smartphones as they are known today had begun. The iPhone had a touch screen, extensive browsing capabilities, incorporated various sensors such as an accelerometer and gyroscope and, most importantly, offered a wide variety of applications with features available only on desktops and laptops. Soon after in 2007, Google announced that they would offer a free operating system to manufacturers Android, and in 2008, HTC signed up to be the first manufacturer to make Android phones after Google backed the project.

The ability to manufacture smartphones with powerful hardware and sensors such as GPS, gyroscopes, etc., led to the development of numerous applications. The two biggest application stores, App Store by Apple and Google Play by Google, offer smartphone users applications ranging from business applications to games and personalization tools. Appbrain.com (Appbrain Home Page, 2015) offers extensive statistics about the number of applications in different categories. The powerful hardware of modern smartphones poses no limitations to application development. Thus, applications such as word processors, spreadsheets, PDF readers, media players, etc., are equally powerful and functional compared to their desktop counterparts.

The introduction of sensors in smartphones enabled the development of a variety of applications that use inputs from them. In cadastre, there is an interest in applications that are able to make area calculations and provide the coordinates of selected points by making use of the embedded GPS sensors. These applications provide a fast and efficient way to gather crowdsourced data. Their interface is in most cases very simple and the instructions they offer make the measuring task easy and not discouraging for the user. Moreover, the ability of many applications to directly export and send data over the web makes data collection and distribution easy and cost effective.

During this work, a number of different applications have been evaluated for spatial data collection. The requirements posed were that the application should be able to measure distances and areas and provide the coordinates of the selected points and/or areas in WGS84 standard. The applications that met the requirements were Distance Tool and iMapIt Lite, both free and available on Apple's App Store (iTunes Preview, 2015).

Distance Tool

Distance Tool allows for easy distance and area calculations (iTunes Preview Distance Tool, 2015). The user can drop points at his/her location using the GPS and then calculate the perimeter and the area of the polygon he/she has formed. The results can be shared via e-mail, which include a file that can be opened only by other devices using Distance Tool or by generating a URL that can be viewed by a desktop web browser, a feature that adds more flexibility [Figure 7.12, right].

iMapIt Lite

This application uses the GPS sensor of the device in order to collect geographic coordinates (iTunes Preview iMapIt Lite, 2015). These coordinates can be used to form lines or polygons. The mapped lines and polygons can be calculated.

The Lite version of the application does not support automatic data export. Upgrading to the pro version, the user can export mappings in DXM format, which is compatible with CAD software, or KML format for viewing on other map-showing applications [Figure 7.12, left].

Other applications

Application markets offer a variety of measuring applications but at the time this experiment was done most of them do not meet the accuracy criteria specified above. For example, GPS Area Measure Free (Google Play GPS Area, 2015) and Connected Farm Scout (Google Play Connected Farm, 2015) applications were not considered for use in this experiment because the former faced issues with correct positioning (although the problem is supposed to have been fixed in the latest update) and the latter does not calculate areas.

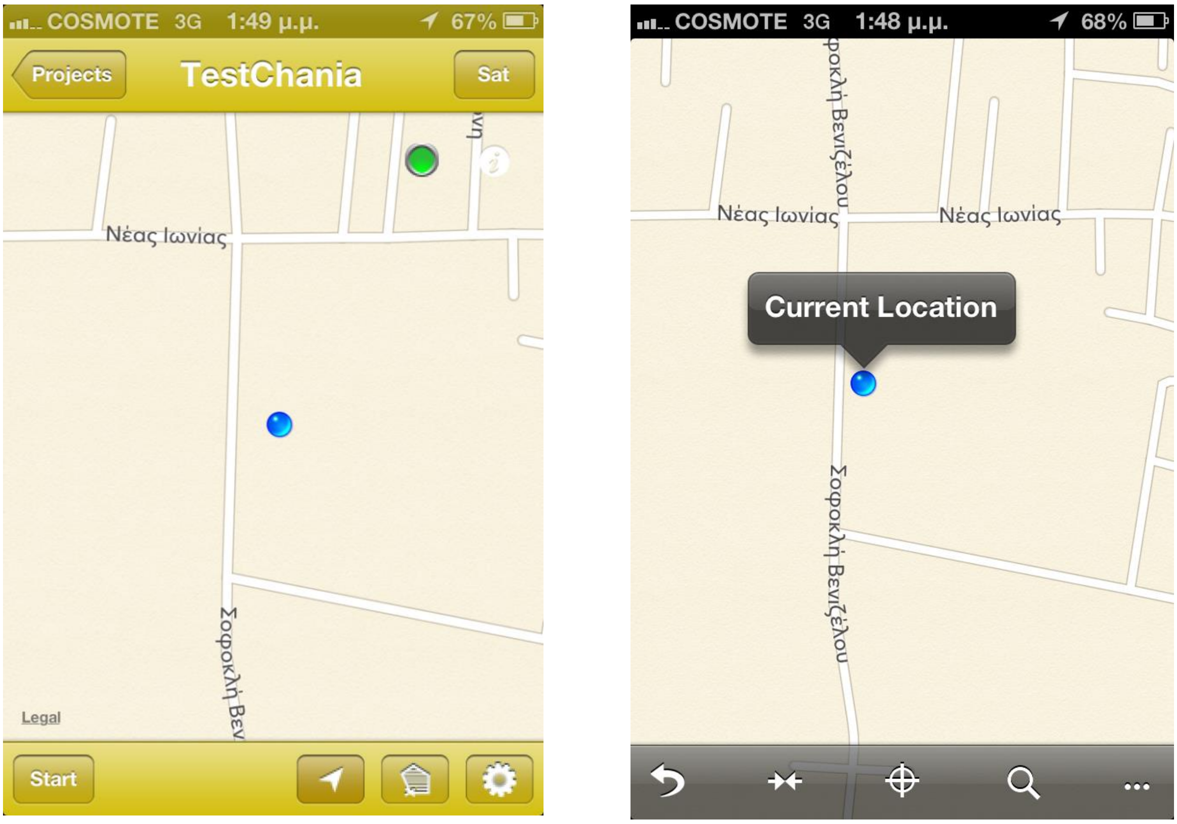


Figure 7-12: The interface of the applications.

EpiCollect.net toolkit

To meet the requirements posed for the attribute data collection and editing, another free-of-charge application was selected, EpiCollect. EpiCollect.net toolkit was developed by Imperial College and as the developers state on their main webpage "The epicollect.net provides a web and mobile app for the generation of forms (questionnaires) and freely hosted project websites for data collection which includes GPS and media by using multiple phones and all data can be viewed centrally by using Google Maps and creating tables and charts" [Figure 7.13]. Aanersen *et al.* (2009) state that EpiCollect was designed to support a two-way communication so that field workers could connect to their project databases simultaneously. According to their research, GPS and Google Maps offer a great opportunity in this direction and the main advantage of the mobile phone is to be used in conjunction with web applications.

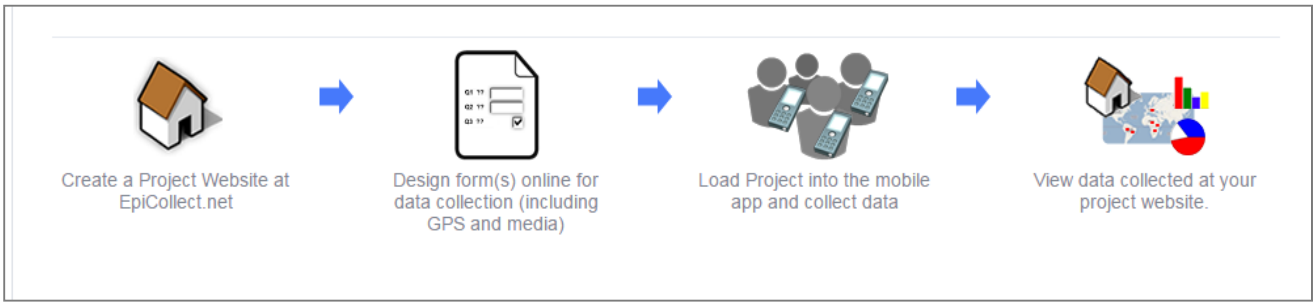


Figure 7-13: The workflow of the EpiCollect process (source: EpiCollect.net website)

The Chania project was first created on the EpiCollect.net website and was named Volunteered_Cadastre. The questionnaire was designed and then was loaded onto the smartphone. The data was stored on the mobile phone and was also accessible by the website.

7.3.4. The crowdsourcing process

The experiment was carried out during a weekend of August 2013 in the district of Eleftherios Venizelos, which is located in the south part of Chania city. Fourteen landowners participated voluntarily and collected GPS tracks of seventeen land parcels in a continuous area covering 80,473.81km^2. Continuous land parcels constitute the area as the urban regeneration planning has only been implemented in a very small percentage. Many parcels in the greater area do not have access to the road network so they remain unutilized. The majority of them do not have any enclosure, although they may belong to different owners and the physical boundaries remain indiscernible to any outsider.

An iPhone 4S was used and data were collected using two mobile applications. The attribute data was collected using the EpiCollect.net toolkit and the spatial data was collected by using the Distance Tool.

The process that was followed in this experiment differed from all previous experiments by a few steps [Figure 7.14]. Compared to all previous experiments, this one required not only follow-up evaluation of the results but also appropriate selection of the toolkits, design of the project in EpiCollect website for attribute data collection and general preparation that may be done once and can then be adopted in various projects.

The beginning of the process was not done by recruiting undergraduate students or by asking for support from the local authorities. Within this experiment, the researcher came directly into contact with the landowners and asked for their assistance in the practical application. This approach satisfied three different statements that it was important to prove practically. First, the participation of volunteers is proportionate to the credibility of the organization that asks for assistance. For example, naming the NTUA as the organization carrying out the application developed the landowners' trust. The involvement of NGOs and universities in data collection and manipulation can only work positively, as highlighted in the design of the general model. Second, the procedures can be easily simplified and bureaucracy can be bypassed. Third, either the procedures should be automated in an easier and quicker way or the participation of landowners in the different areas of interest is of vital importance for an experiment's success and approval by the local community.

As a third step of the process, the landowners were trained by the researcher, who kept a leading role as a supervisor, offering instructions and explaining the aims of the experiment. The landowners were asked to collect spatial data not for the current condition of their land parcels but for the coming one after the implementation of the general plan in the area. The volunteers were asked to indicate the future boundaries that exist only on the general plans.

The next step of data collection was divided into two parts: collecting attribute and spatial data separately with the aid of different mobile applications. The collection of attribute data was based on volunteers completing the form designed using the EpiCollect tool and the spatial data was collected with Distance Tool and iMapIt Lite applications. All mobile toolkits for spatial data collection were selected to satisfy four main factors: being free of charge and meeting the requirements of measuring distances and areas, giving coordinates in WGS 84 and depicting the measuring area on the map. EpiCollect.net satisfied the requirements posed by the researcher in the form of the questionnaire and was the best choice for attribute data collection with the geotagging of photos regarding land parcels.

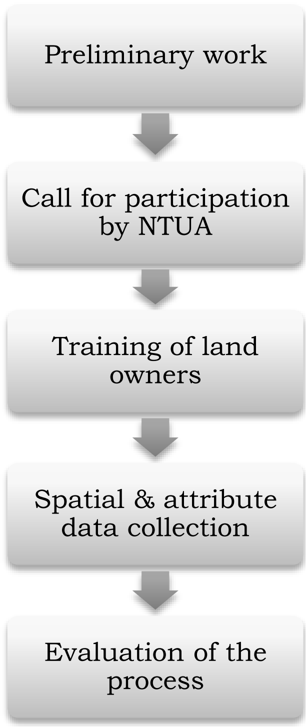


Figure 7-14: The workflow of the fourth experiment.

The last step of the process comprised downloading the data, spatial data manipulation and evaluation afterwards at the laboratory. The design of this experiment satisfies a few of the principles that were posed by the general model previously introduced, including that manipulation of data can be completed with the participation and aid of undergraduate students. Maintenance and storage of data can also be guaranteed by the official mapping agency, which is responsible for this part of the work.

Finally, this experiment is different to all previous experiments, as it serves a more general target. It is applied in an area where the compilation of the cadastral survey was concluded in 2006 without any difficulties. However, the area faces a different land administration issue that can be approached by crowdsourcing techniques and the principal components that were introduced in the general crowdsourced model for cadastral surveys, which is to identify their new property boundaries according to the urban regeneration plan.

7.3.5. Collecting attribute data

The online collection of attribute data simulated the process followed by the official mapping agency for the collection of the data in the first phase of the cadastral survey. The EpiCollect.net application was used to collect the attribute data, to geotag photos of the area of the experiment and create an online toolkit project developed by the research team named Volunteered_Cadastre. The first step of the cadastral survey process states that the right holders submit declarations to the cadastral survey offices and the registration of the declared rights is added to a digital database. The owners are obliged to complete their data and submit their titles in a hard copy format. The contractor who has undertaken responsibility for that specific area of interest digitizes the information in a second step. In the case of any ambiguities, corrections or completions, the procedure should be repeated in a new cycle between the owners, the contractor and the official mapping agency.

The idea to simulate the process targeted the simplification of the process, the elimination of the time and cost and introduced the active participation of citizens in the online submission of cadastral data. The attribute data was collected with the aid of EpiCollect.net toolkit installed in an iPhone 4S device. All entries collected with EpiCollect also included the GPS location and a photo [Figure 7.16]; an opportunity offered by the application and which proved helpful in the identification of the land parcel. The project was first designed on the EpiCollect website with the aid of the features provided by the designers of the application. The project was named ***Volunteered_Cadastre*** and was designed with instructions for users. The created form contained three types of questions: personal data, data about the land and the buildings, the title of ownership and any special characteristics of the parcel [Figure 7.15].

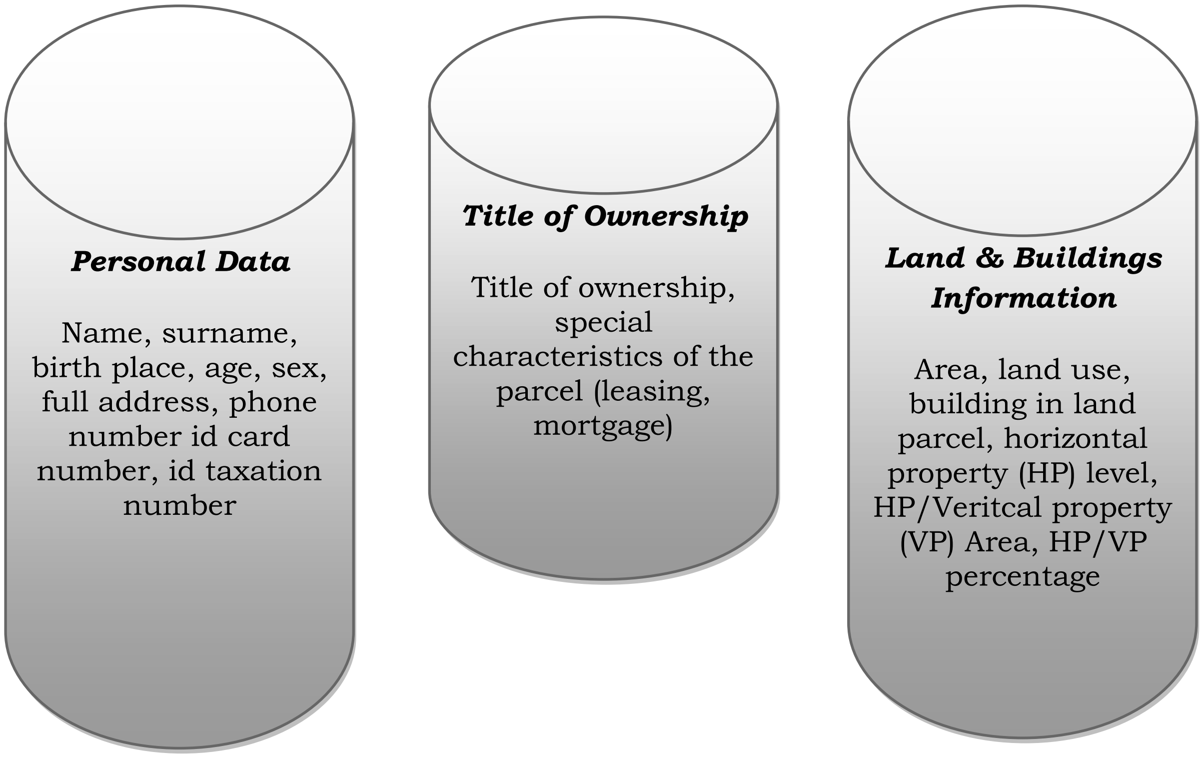


Figure 7-15: The content of the attribute data collection.

The experiment indicated that landowners found it easy to complete the form. Although privacy issues are out of the scope of this research, it should be underlined that no participants were reluctant to grant personal data. It is clear not only that the new generation confronts privacy issues in a more open manner, but that the majority of citizens who trust the state may act proportionally.

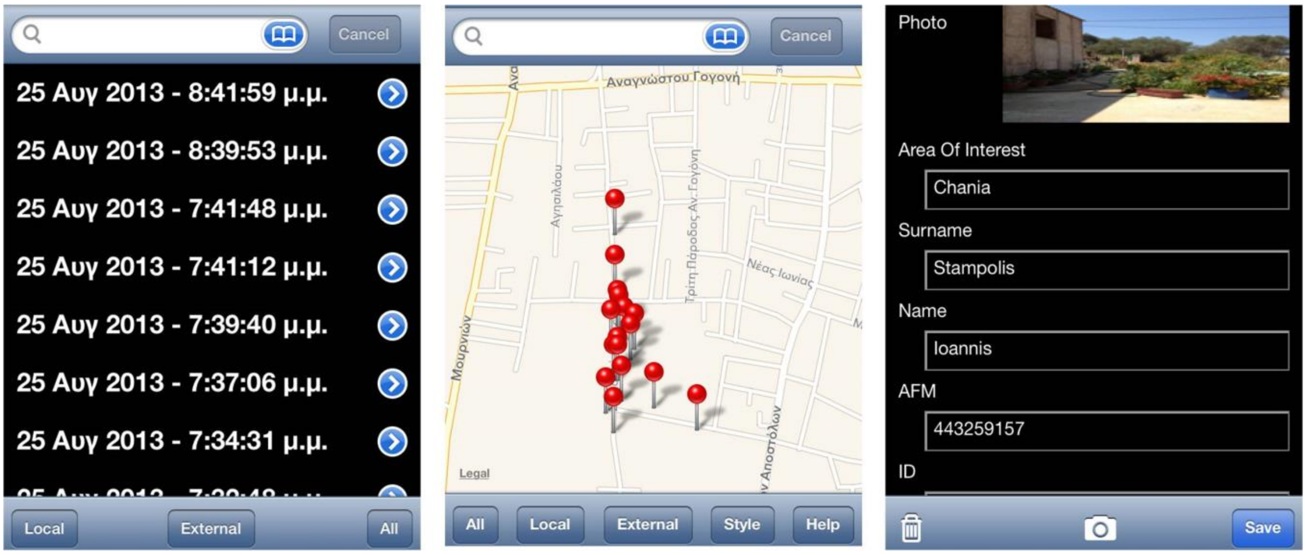


Figure 7-16: The interface of EpiCollect for the attribute data collection

The aim of the project is not to copy all the required fields of the hard copy declaration and reproduce them in the online application. The aim is to simulate the process and reduce repeated cycles between owners and the official mapping agency in the cadastral survey office.

The only disadvantage that was noted is that the EpiCollect website does not maintain the data for a long period of time. This inconvenience would be bypassed by the proposal that data storage is to be done by the national mapping agency within the general cadastral model.

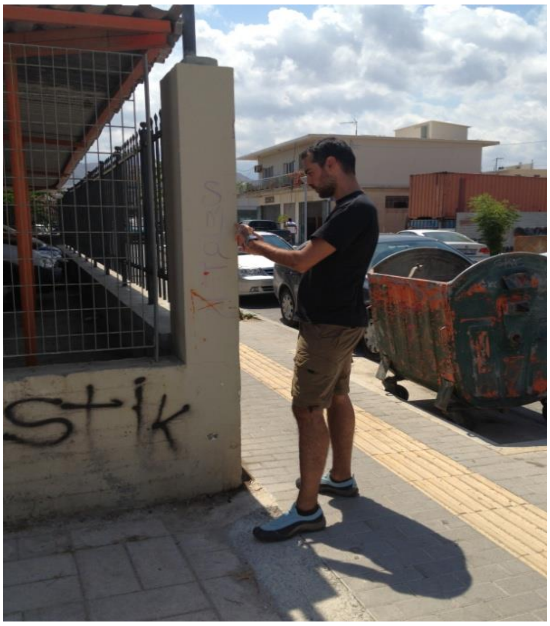


Figure 7-17: A volunteer collecting spatial data.

7.3.6. Collecting spatial data

The landowners were also asked to collect the spatial data with the aid of the iPhone 4S and by using the Distance Tool application [Figure 7.17]. The Distance Tool application was evaluated as easy to use and was selected in comparison to the iMapIt Lite application because it provided supplementary coordinates for each single GPS measurement. The use of only one application for spatial data collection was also expected to facilitate the evaluation of the results and the elimination of errors and deficiencies between the different applications. The volunteers needed only to press one button at the edges of their parcel boundaries [Figure 7.18]. The coordinates were recorded in a separate sheet by the team leader and were extracted in TXT format. They were transformed to HGRS 87 and were imported in a DXF file. The results were compared to the initial data provided on the General Plan.

One of the great advantages of the application is that after collecting the GPS tracks, the parcel is depicted on the map and its area is given. Thus, errors in position or in size can be easily noticed in the field and if necessary the measurements can be repeated.

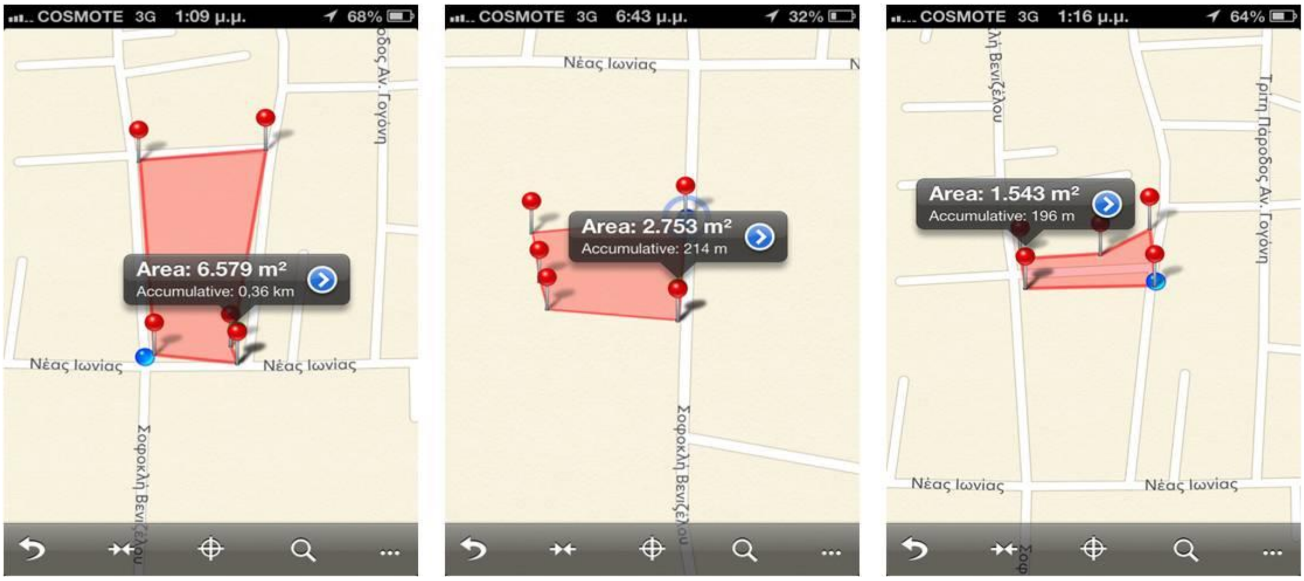


Figure 7-18: The interface of the Distance Tool application within the spatial data collection

The distance was calculated by recording the coordinates of the edges of the actual boundaries and the measured coordinates and by applying the equation $D = \sqrt{\Delta X^2 + \Delta \Psi^2}$, . The distance indicated a variation between the measured points and the actual points, which fluctuates from 0.45 to 13.75 meters. The analysis of the results showed that the urban part of the application suffers the greatest failures. Only 16.67% of the measured points diverge less than 1.8 meters, however 37% diverge less than 4 meters. The average is 5.05 meters. The highest diversion between the measured and the actual point is 13.75 meters and the lowest is 0.45 meters.

point	Xm	Ym	Xa	Ya	distance
1	501810,1180	3928449,0240	501808,9720	3928449,7905	1,3787
2	501855,4610	3928460,1240	501856,0270	3928457,3102	2,8702
3	501882,6660	3928471,2210	501879,4550	3928468,6280	4,1272
4	501873,6020	3928449,0380	501877,2090	3928447,9695	3,7619
5	501810,1200	3928437,9330	501809,8300	3928439,8560	1,9447
6	501810,1230	3928426,6800	501810,1760	3928435,8690	9,1892
7	501882,6730	3928437,9490	501876,7660	3928443,8870	8,3757
8	501855,4910	3928327,0380	501863,5485	3928322,2767	9,3591
9	501819,2140	3928327,0290	501818,9340	3928321,6550	5,3813
10	501819,2603	3928315,6730	501819,3440	3928321,6550	5,9826
11	501864,5620	3928315,9490	501865,7173	3928310,2716	5,7938
12	501864,5720	3928271,5870	501862,1903	3928264,4074	7,5643
13	501819,2260	3928271,5770	501819,5397	3928275,1000	3,5369
14	501737,6100	3928238,2870	501739,8233	3928244,6518	6,7386

15	501810,1620	3928249,3930	501810,9238	3928250,9080	1,6957
16	501801,1040	3928193,9390	501805,4878	3928198,9654	6,6695
17	501746,6860	3928205,0180	501741,7622	3928200,8951	6,4220
18	501746,6880	3928193,9270	501747,1421	3928193,9283	0,4541
19	501810,1740	3928193,9410	501807,8594	3928191,0028	3,7404
20	501801,1120	3928160,6670	501805,4345	3928160,5961	4,3231
21	501764,8340	3928160,6590	501761,6934	3928164,5080	4,9677
22	501764,8390	3928138,4780	501759,8880	3928140,5100	5,3518
23	501792,0470	3928138,4840	501791,4750	3928133,8510	4,6682
24	501801,1190	3928127,3950	501804,0040	3928131,2250	4,7950
25	501801,4693	3928097,3300	501801,7693	3928097,7300	0,5000
27	501773,9130	3928116,2990	501769,9046	3928115,3743	4,1137
28	501773,9110	3928127,3890	501765,9467	3928125,3152	8,2299
29	501810,1980	3928083,0350	501808,7531	3928089,3851	6,5124
30	501828,3370	3928083,0390	501828,9037	3928092,3385	9,3168
31	501828,3394	3928071,9483	501830,2328	3928072,3824	1,9425
32	501810,2030	3928060,8540	501809,6750	3928074,5884	13,7445
32	501946,2350	3928105,2470	501948,4340	3928100,8074	4,9544
33	502018,7930	3928094,1740	502021,3147	3928085,4773	9,0549
34	502009,7370	3928038,7190	502008,0353	3928035,6665	3,4948
35	501936,8280	3928061,1878	501943,2410	3928049,3318	13,4793
36	501864,6000	3928149,5900	501870,3291	3928149,4141	5,7318
37	501900,8800	3928149,5470	501898,6927	3928145,7985	4,3400
38	501900,8800	3928138,5080	501897,6539	3928134,4251	5,2036
39	501873,6720	3928138,5020	501869,0606	3928137,2118	4,7885
40	501810,1790	3928171,7590	501813,1232	3928170,8057	3,0947
41	501855,5280	3928160,6790	501854,7174	3928159,6039	1,3464
42	501855,5330	3928138,4980	501852,9777	3928141,3538	3,8321
43	501810,1840	3928149,5780	501813,8357	3928149,5939	3,6517
44	501819,2430	3928193,9430	501814,7115	3928198,5210	6,4415
45	501864,5893	3928193,9530	501861,5556	3928192,3031	3,4533
46	501855,5260	3928171,7700	501858,1927	3928168,0725	4,5588
47	501819,2480	3928171,7610	501813,6341	3928177,2852	7,8761
48	501819,2346	3928231,3722	501817,4025	3928231,4990	1,8365
19	501864,5820	3928227,2240	501861,2659	3928228,4336	3,5298
50	501864,5993	3928193,9530	501861,8526	3928192,2609	3,2261
51	501819,2430	3928193,9430	501814,7115	3928198,5210	6,4415
52	501819,2330	3928238,3050	501817,7965	3928238,3422	1,4370
53	501819,2310	3928249,3950	501821,1379	3928247,4139	2,7497
54	501864,5770	3928249,4060	501861,9087	3928252,4105	4,0183

Table 7-2: The measurements from the handheld GPS with the actual points and their diversion

The GPS tracks were linked to create the boundaries of the parcels and the result without any editing is given in Figure 7.19 (left) below. The right-hand side of Figure 7.19 shows two adjacent land parcels with the lowest diversion between measured and actual points in green and the highest in yellow.

Figure 7-19: The measured land parcels in red. The most precisely measured point in green (0.45 meters) and the most remote in red (13.75 meters)

However, the experiment indicated that the use of high-resolution orthophotos in urban areas might bring the required accuracy to the result. Thus, in this experiment, selected parcels with buildings were edited on the orthophotos and the result was improved [Figure 7.20]. Rural parcels where the fences are distinguished on the orthophotos may also be improved afterwards at the office. The combination of two different technical approaches was the best solution for follow-up editing. Furthermore, the collection of more GPS tracks than required for the depiction of the parcel may contribute to its better presentation. In two parcels where owners collected more GPS tracks than required, the shape was produced with higher accuracy.

Figure 7-20: The land parcels corrected on the orthophotos.

7.3.7. Results

All previous statements highlighted in the third experiment are verified in this experiment as well: the application was quick, inexpensive and easy for volunteers to participate. Crowdsourcing techniques also offer flexibility in design and selection of the best practices to serve the specific purpose. In the sociological framework, the workshops constitute the most important part of the experiment. The volunteers gain familiarity with the new technologies, the purpose and the necessity of the application. Only in one case was a citizen reluctant to participate and the boundaries of his parcel were instead verified by the other adjacent owners and the existing fence.

The experience also indicated that the combination of different techniques such as spatial collection with handheld GPS and digitization on orthophotos might improve accuracy in semi-urban and urban areas. The technical restrictions and the accuracy issues that are presented in this experiment were only recently bypassed by Mourafetis *et al.* (2014) who presented a GIS application that uses mobile GPS only for rough positioning in the field. The volunteers can then identify the boundaries of their property with accuracy on the basemap used. Jones (2013) first introduced the idea of the LADM in the cloud, a GIS platform incorporating global basemaps that is supported by Android or iOS smartphones.

Two main questions are posed after the evaluation process concerning the unpredictable human factor of citizens' participation and the required accuracy depending on the scale of the produced map. The first one concerns the volunteers who may collect, edit or delete data by accident or deliberately. When training is missing, a volunteer may be unable to understand the technical procedure, or a simple human-error factor is imported, leading to possible deficiencies. If conflicts between landowners exist, incorrect information may be deliberately imported into the system. In this case, gross errors may be found in the editing process or information may get lost. The difficulty may be bypassed if the participation of volunteers is accelerated and the errors of one participant may be corrected by another's correct tracks. The accuracy of the result becomes an endless conversation, however, and the desired scale of the map is the key factor of the whole process. Taking into account the results of the experiment, a 1:500 map may not be ideal for geometric accuracy but only for determining a parcel's location; however a 1:1000 map can serve the requirements of cadastral mapping. It should also be taken into consideration that accuracy might be improved if landowners submit spatial documentation such as topographic diagrams, etc.

The main disadvantage noted within the experiment is that although the volunteers were very willing to participate in the experiment, a lack of smartphones or other technological devices that could facilitate their contribution to the experiment was recorded. Lack of equipment has been predicted in the design of the general crowdsourcing model for cadastral surveys, which can be filled with the participation of the public sector.

7.4. Concluding remarks

Both experiments indicated that cadastral surveys might be supported by crowdsourcing techniques especially in the first phase of the cadastral survey where interim cadastral maps are designed. Technically, the procedures are improved day by day. From a sociological perspective, landowners are willing to participate. The most significant outcome of the practical applications is the enrichment of the general cadastral model with components gained practically.

All practical experiments reflect the international trend in the willingness of the different parties of the state and the owners to participate in the simplification of the procedures and elimination of the cost.

To sum up, the seventh chapter has some significant outcomes that are summarized in the table below.

➢ Both experiments indicated that decision making policies without the support and the participation of citizens suffer severe failures and delays.
➢ Both experiments indicated a quick, inexpensive and flexible methodology that gained the approval of the landowners.
➢ New technologies may bypass bureaucracy and the hard copy submission of the declarations to the cadastral offices.
➢ Registration fees should be reduced in reciprocation of landowners' participation in the implementation of this national target.
➢ Handheld GPS may be used for positioning and measurement in urban

	areas, however, editing afterwards in the office by the experts is inevitable. Handheld GPS is proposed for use only for rough positioning and not measurement in cases where orthophotos are available. In rural areas, the use of handheld GPS returns better results. Collection of more GPS tracks than required may facilitate the process.
➢	The combination of different technical approaches may accelerate the accuracy of the result.

Table 7-3: Concluding remarks of the seventh chapter

8. RESULTS, DISCUSSIONS & FURTHER PROPOSALS

8.1. Introduction

The aim of this study has been to produce keynotes, main lessons, principal components, practical applications and essential proposals within a potential model for the introduction of crowdsourcing techniques in Land Administration Systems. The research explored in depth the technical and sociological aspects that derive from this specific context and investigated theoretically and practically in this direction. Legal aspects and in particular security concerns in terms of private data are out of the scope of this study. The Hellenic Cadastre project was used as a guideline, however the research generalized its proposals and findings so that they may be applied in various land administration projects worldwide. To deal with this challenge, the theoretical findings of the research community and previous practical experience were analyzed. The research also focused on a potential model and checked its functionality by improving its deficiencies and its content with the lessons gained from practical experience. Four different practical experiments were designed and applied so that the theoretical knowledge could be improved by practical outcomes.

This last chapter summarizes the findings and categorizes them into three basic outcomes: general, technical and sociological. It also presents a brief list of potential projects in land administration that can flourish with the aid of crowdsourcing techniques and various general parameters that have not yet been explored.

Table 8.1 indicates the main components of this last chapter.

➢ Discussion on general technical and sociological principles.
➢ Analysis of the research outcomes.
➢ Proposals for further research and potential investigation.

Table 8-1: Predominant components of the eighth chapter

The research indicated that crowdsourcing techniques do not just present a temporary solution as they suggest a viable alternative in a variety of projects and case studies. The current research introduces a holistic approach to the VGI philosophy and determines the framework for its application in land administration projects.

8.2. Discussion

The research proposed the principles for the creation of a general model that could be introduced into a variety of land administration issues. Privacy issues were out of the scope of this research. There are two main reasons for this: (a) the new generation understands privacy in a different and more open way than the previous generation and (b) experience gained from the practical experiments showed that privacy issues are bypassed when credibility and trust exist between volunteers and the state.

The perception that VGI techniques may be adopted only in developing countries or in countries that suffer multiple financial problems has only recently been recognized as anachronistic. The research has demonstrated that, in civilized societies that put citizens at the center of decision making policies and where there is a lack of governmental data, the quest of suitable datasets can lead to the initiation of VGI projects. The VGI approach is not a need; it is a trend and should be defined within this specific framework.

The technical factors behind VGI were explored in a general way, however the field is wide and various aspects could be more developed than those explored in this thesis. Technical keynotes were developed from the research and can be modified depending on the nature of each project.

The economics firmly support the implementation of such a model; and registration fees should be reduced for the landowners who voluntarily participate in this project. This elimination of fees may work as a motivation for the majority of the participants. The whole cost of the procedure will also be reduced with the elimination of contractor's time and duplication of work in case of errors, as a result of the active involvement of the landowners and the contribution of the public sector to equipment and other facilities. Another significant factor that keeps cost low is that the data collection, editing and storage can be incorporated into one stage. The storage and maintenance of the data will be done by the national mapping agency in accordance with its evaluation.

The research has already predicted the need for coordination with the INSPIRE directive such that any SDI must be designed to be contemporary and up to date with the EU's requirements and restrictions. According to the INSPIRE directive, institutions and other bodies of the Community with access to spatial data sets and services should be harmonized with the principles posed by the directive. Crowdsourcing techniques as well as the general model designed in this study both firmly support the specific statements in the directive.

Previous experience indicates that it is vital that SDIs broaden in terms of agreements on technology standards, institutional arrangements and policies enabling the discovery and facilitating the availability of, and access to, spatial data.

8.3. Findings

The results of the current research are categorized in three different domains: technical, sociological and more general key factors for the potential crowdsourced cadastral process. The outcomes below have been derived from the practical and theoretical investigation of this study, and present its main results.

8.3.1. General outcomes

- Firstly, the research indicated that crowdsourcing techniques may adhere to good practice, and they are viable projects and fit-for-purpose solutions to complex problems that require fast, low-cost solutions. They are characterized as inexpensive, relatively quick and flexible approaches.

- Projects have been applied on a variety of tasks at local or national level and their output has served multiple purposes, not just those for which they were originally designed. Experience shows that general processes can be adapted to special needs and modified so that they serve specific targets.

- The new GIS era is directly linked to the democratization of data with the aid of VGI in a large number of land management projects including cadastre. Data collection is affected by these changes and so is data editing and sharing.

- Governmental crowdsourced projects should be well defined to reduce overlapping duties and responsibilities between the various parties that participate in an experiment. However, the process should also be flexible so it can be adapted to the nature of each area or to local needs.

- The contribution of the parties involved may reduce the time required for the project and ensure that it covers the special needs of experts.

- Not all land administration projects work with the aid of crowdsourcing techniques: cadastre for forest areas, mapping of archaeological sites, determination of coastal zones or areas where boundaries are not easily recognized on orthophotos for example are a few examples that either require great accuracy or face other restrictions. Briefly, it is hard to delimit the boundaries of an archaeological site in the field with a handheld GPS when official coordinates are given in the Official Government Gazette; and it is difficult to determine coastal zones or forested areas affected by private ownership when disputes among landowners are recorded in courts.

- The creation of interim cadastral maps is not included in the above list of restrictions and may be supported by crowdsourcing techniques. The theoretical and practical experience gained by the current research indicated that the first phase of cadastral mapping could be implemented with the aid of crowdsourcing techniques and the support of local volunteers who constitute an essential tool for successful implementation.

- Concerns over the maintenance and viability of the quality of the data experienced in other short-term projects may be avoided with the support of the official mapping agency, which will be responsible for data storage and updates when needed. In other words, continuation and sustainability beyond the initial project is guaranteed with the active participation of the state.

- Previous outcomes indicate that crowdsourced applications can flourish and endure, especially if they receive support from the governments and receive acceptance by the official partners. A semi-hybrid cadastral crowdsourced model also needs governmental support and encouragement.

8.3.2. Technical outcomes

- Previous research, as well as the current thesis, has proved that technical issues do not constitute a limiting factor in VGI approaches. This is also valid in the context of cadastral procedures.

- The weakness of using a handheld GPS may be bypassed in cases where accurate basemaps exist (e.g. orthophotos).

- The required accuracy can be reached with a combination of various technical solutions. The use of accurate and recent orthophotos in combination with the auxiliary use of GPS may improve the quality of the results.

- Technical approaches may vary depending on the required accuracy but also on the nature of the area concerned. Urban areas can be mapped using dynamic maps or high-resolution orthophotos. Field surveys with inexpensive equipment – even a handheld GPS – may be adopted in rural areas and areas without attached construction. Handheld GPS may be used in urban areas for rough positioning and subsequent editing either online or offline by experts. In rural areas, the use of handheld GPS may return acceptable results. The collection of more GPS tracks than the minimum required may facilitate the process. This may be applied in areas where no accurate basemaps exist, such as developing countries.

- The use of OSM offers great potential for cadastral purposes in countries where no better basemaps exist. In other words, sources of VGI data such as OSM are growing increasingly important across a range of thematic areas and user communities. Among other advantages, OSM offers the opportunity for real-time monitoring of the work supported by up-to-date databases and also offers simultaneous technical assistance.

- In developed countries, the use of high-accuracy basemaps for the identification of ownership further accelerates the accuracy of results. This requirement is satisfied by the use of LSO and VLSO provided by the national mapping agency.

- Interim cadastral maps can be better designed with the increased participation of owners and other volunteers. For the Hellenic Cadastre, the submission of hard copy declarations of ownership can be easily replaced by the active participation of landowners and the adoption of new technologies.

- Moreover, the combination of commercial low-cost and free-of-charge open software has proved essential for any project's success. Combining various tools in different contexts can widen the technical horizons of an application and create new opportunities.

- In conclusion, new App-like technologies, free-of-charge applications in smartphones, open-source software and easy-to-use web tools constitute the future for decision making policies as well as for cadastre.

8.3.3. Sociological outcomes

- Altruistic motivations may remain the principal theoretical incentive for the volunteer participation, however targeted motivations should be used to ensure and encourage participation in cadastral surveys. The volunteers participate to help their neighborhood, to develop the market, to unblock their properties or to see a reduction in registration fees and taxation.

- In general, the experiment also indicated that large-scale land projects such as the

Hellenic Cadastre suffer severe failures and delays without the support and participation of citizens. The participation of volunteers and citizens is a sign of a civilized society that respects its citizens. Close collaboration between government and the public may guarantee the approval of hard decisions.

- The study identified the most important oriented land management initiatives in participatory mapping for the majority of volunteers, which are summarized in five main motivations: as a cadastre is created to help the economy flourish, there is an increased need to accelerate its compilation procedure; a cadastre will eliminate land disputes and protect private and public tenure.

- This research indicated that volunteer participation is motivated by general incentives in cadastral surveys such as the acceleration of the official process, the elimination of the cost and errors of the official procedure, the acquirement of free geospatial data and the closure of the gap towards reliable geospatial data.

- In all voluntary incentives, participants satisfy personal motivations as well as social ones. This research recorded career investment, personal satisfaction, introduction to social networks and improvement of technical skills among these.

- Training at the beginning of every practical application has been proved to be one of the most important factors: volunteers become informed about the purpose and benefits of the project, and they learn how to work and handle new technologies and data.

- The participation of young people facilitates the use of new technologies and the recruitment of undergraduate students of the SRSE, Geography or other schools simplifies and accelerates this process. Students can play a vital role in the training stage and in data collection and processing as team leaders and data registers.

- The practical applications indicated that recruitment of volunteers may be possible for the purposes of every crowdsourced application. The thesis proved that the recruitment of students and landowners might guarantee the evolution and viability of the cadastral project.

- Strong collaboration between various organizations, students, the public sector, the national mapping agency, who are experts in different parts of a project, is key to success.

- The from-a-distance participation of landowners who may live abroad and can easily declare their ownership online is an essential facility that satisfies two basic parameters: owners who live abroad can personally declare their ownership without involving an attorney and can even feel the satisfaction of contributing to a national goal.

8.4. Proposals

Crowdsourcing techniques can potentially be applied to various land administration projects. The international experience and the current study indicated that the application of VGI to governmental projects is largely based in three main categories: disaster response, land management and general public administration. However, there are many unknown parameters and issues still to be explored.

The VGI philosophy, almost ten years after the term was first coined, is considered to be a promising and still unexplored field with various elements still to be developed. Some aspects have been explored as a result of interest from the academic community but crowdsourcing techniques are adaptive and flexible in various circumstances, meaning there is scope for this to be further developed.

This research could be further extended in terms of its technical, social and legal aspects in order to test various algorithms using the data collected from previous practical experiments. It will also focus on related projects that not only have impact in Greece but also worldwide. In the context of land administration, further research should be conducted into projects related to the denationalization of public lands, planning and land expropriation as these result in the most significant disputes among landowners and the state. The reason for this is quite simple: the decisions are taken by the state without taking citizens' opinions and active participation into account.

It is a general fact that one of the greatest challenges that the research community will have to face within the next decades will be on land-related issues. The use of crowdsourcing techniques will be inevitable and the only way for this to work efficiently is for the requirements of such techniques to be proposed by experts right from the beginning.

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APPENDIX I

Γενικές Ερωτήσεις

1. Έχετε Η/Υ;	Ναι	Όχι
2. Έχετε σύνδεση στο internet;	Ναι	Όχι
3. Έχετε GPS;	Ναι	Όχι
4. Έχετε κινητό με ενεργοποιημένη σύνδεση στο internet;	Ναι	Όχι
5. Διατηρείτε κάποιου είδους ιστοσελίδα; Αν ***Ναι***, προσδιορίστε: α. Σελίδα κοινωνικής δικτύωσης (facebook, linkedin κ.λπ.) β. Σελίδα ενημερωτικού χαρακτήρα γ. Σελίδα προώθησης προϊόντος ή καταστήματος δ. Ιστολόγιο (Blog) ε. Άλλο (Προσδιορίστε: …………………….)	Ναι	Όχι

Ειδικές Ερωτήσεις

A. Διαδικτυακοί χάρτες και OpenStreetMap

A.1. Χρησιμοποιείτε χάρτες από το διαδίκτυο;	Ναι	Όχι

Αν ***Ναι,*** κατατάξτε ανάλογα με τη χρήση από το 1(***καθόλου***) ως το 5(***πάρα πολύ***) τους παρακάτω διαδικτυακούς χάρτες που χρησιμοποιείτε πιο πολύ.

Google Maps	1	2	3	4	5
Bing Maps	1	2	3	4	5
OpenStreetMap	1	2	3	4	5
DriveMe Maps	1	2	3	4	5
Terra Maps	1	2	3	4	5
Navigation.gr Maps	1	2	3	4	5

Α.2. Έχετε χρησιμοποιήσει ποτέ το OpenStreetMap;	Ναι	Όχι

Αν ***Ναι***, βαθμολογήστε από το 1(***πολύ κακό***) ως το 5(***πολύ καλό***) τα παρακάτω χαρακτηριστικά του.

Πληρότητα οδών – περιοχών	1	2	3	4	5
Παρουσίαση χάρτη (χρώματα κλπ)	1	2	3	4	5
Ονοματολογία Οδών	1	2	3	4	5
Ύπαρξη Σημείων ενδιαφέροντος	1	2	3	4	5

Β. Εθελοντική Γεωγραφική Πληροφορία

Το OpenStreetMap είναι ένας διαδικτυακός χάρτης που δημιουργήθηκε εξ' ολοκλήρου από απλούς πολίτες που εθελοντικά συνέλλεξαν και επεξεργάστηκαν χωρική πληροφορία. Ο κάθε χρήστης μπορεί να συλλέξει χωρικά δεδομένα με το GPS του, να τα ανεβάσει στο διαδίκτυο και να δημιουργήσει το δικό του χάρτη χωρίς περιορισμούς χρήσης.

Β.1. Έχετε συμμετάσχει ποτέ εθελοντικά σε κάποια κοινωνική οργάνωση ή κίνηση;	Ναι	Όχι
Β.2. Έχετε συμμετάσχει ποτέ εθελοντικά σε χαρτογράφηση;	Ναι	Όχι

Β.3. Θα συμμετείχατε εθελοντικά σε χαρτογράφηση;	Ναι	Όχι

Αν ***Ναι,*** βαθμολογήστε από το 1(***καθόλου***) ως 5(***πάρα πολύ***) τους λόγους για τους οποίους θα συμμετείχατε εθελοντικά στη χαρτογράφηση μιας περιοχής.

Β.3.1.

Για συνεισφορά στο κοινωνικό σύνολο	1	2	3	4	5

B.3.2

Για επίσπευση της διαδικασίας της Κτηματογράφησης στην περιοχή σας	1 2 3 4 5
Για μείωση του κόστους δημιουργίας Κτηματολογίου στη χώρα	1 2 3 4 5
Για να αποκτήσετε δωρεάν χωρικά δεδομένα	1 2 3 4 5
Λόγω έλλειψης αξιόπιστων χωρικών δεδομένων στην περιοχή σας	1 2 3 4 5

B.3.3

Ως μέσο για εύρεση εργασίας	1 2 3 4 5
Για την απόκτηση τεχνογνωσίας & εμπειρίας πάνω στο συγκεκριμένο Αντικείμενο	1 2 3 4 5

B.3.4

Για Προσωπική Ευχαρίστηση	1 2 3 4 5
Για μείωση του Άγχους	1 2 3 4 5
Για Προσωπική Προβολή	1 2 3 4 5
Για Ένταξη σε Κοινωνικά Δίκτυα	1 2 3 4 5

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B.4. Βαθμολογήστε από το 1(***καθόλου***) ως 5(***πάρα πολύ***) κατά πόσο είστε διατεθειμένοι να συνεισφέρετε εθελοντικά με τη συλλογή και επεξεργασία χωρικών δεδομένων στη δημιουργία χάρτη:

Για Πλοήγηση	1 2 3 4 5
Για Χαρτογράφηση	1 2 3 4 5
Για να περιλαμβάνει τα προσωπικά σας σημεία ενδιαφέροντος (εστιατόρια, αξιοθέατα κ.λπ.)	1 2 3 4 5
Για την αντιμετώπιση καταστάσεων εκτάκτου Ανάγκης (σεισμός π.χ)	1 2 3 4 5

Γ. Ελληνικό Κτηματολόγιο

Γ.1. Έχει ενταχθεί η περιοχή σας στο Κτηματολόγιο;	Ναι	Όχι	Δ.Γ.

Γ.2. Βαθμολογήστε τις παρακάτω προτάσεις από το 1 (***διαφωνώ απόλυτα***) ως το 5 (***συμφωνώ απόλυτα***) ανάλογα με το κατά πόσο διαφωνείτε ή συμφωνείτε.

Η ύπαρξη Κτηματολογίου αποτελεί αναπόσπαστο στοιχείο για τη σωστή Διαχείριση Γης.	1	2	3	4	5
Η ύπαρξη Κτηματολογίου θα μειώσει τις καταπατήσεις, την αυθαίρετη δόμηση και θα κατοχυρώσει την ιδιωτική περιουσία.	1	2	3	4	5
Η ένταξη μιας περιοχής στο Κτηματολόγιο έχει θετική επίδραση για την ίδια την περιοχή.	1	2	3	4	5
Η ένταξη μιας περιοχής στο Κτηματολόγιο θα βοηθήσει τους ιδιοκτήτες γεωτεμαχίων ως προς την πιο γρήγορη αξιοποίηση τους.	1	2	3	4	5
Το Κτηματολόγιο γίνεται για δικαιότερη φορολόγηση.	1	2	3	4	5
Η ένταξη περιοχών στο Κτηματολόγιο είναι χρονοβόρα και δαπανηρή διαδικασία.	1	2	3	4	5
Το Κτηματολόγιο γίνεται για εισπρακτικούς λόγους.	1	2	3	4	5

Γ.3 . Είστε διατεθειμένοι να συνεισφέρετε εθελοντικά με τη συλλογή και επεξεργασία χωρικών δεδομένων στη δημιουργία:

Του Κτηματολογίου	Ναι	Όχι

Αν ***Ναι***, βαθμολογήστε τις παρακάτω προτάσεις από το 1 (***καθόλου***) ως το 5 (***πάρα πολύ***) ανάλογα με τους λόγους που θα σας έκαναν να συμμετάσχετε:

Για να μειωθεί το κόστος της Κτηματογράφησης	1 2 3 4 5
Για να μειωθεί ο χρόνος της Κτηματογράφησης	1 2 3 4 5
Για να έχετε τον έλεγχο των χωρικών δεδομένων ώστε να μειωθούν τα λάθη	1 2 3 4 5
Ως ενεργός πολίτης που αναγνωρίζει την ανάγκη ύπαρξης Κτηματολογίου	1 2 3 4 5

Αν ***Όχι***, βαθμολογήστε τις παρακάτω προτάσεις από το 1 (***καθόλου***) ως το 5 (***πάρα πολύ***) ανάλογα με τους λόγους που θα σας έκαναν να μην συμμετάσχετε:

Λόγω έλλειψης εμπειρίας	1 2 3 4 5
Λόγω έλλειψης χρόνου	1 2 3 4 5
Λόγω έλλειψης ενδιαφέροντος	1 2 3 4 5

Προσωπικές Ερωτήσεις

Δ.1. ***Φύλο***

Γυναίκα	
Άντρας	

Δ.2. ***Ηλικία***

18 – 30
31 – 40
41 – 50
> 51

Δ.3. ***Εκπαίδευση***

Απόφοιτος Λυκείου
Φοιτητής
Κάτοχος Πτυχίου Τ.Ε.Ι
Κάτοχος Πτυχίου Α.Ε.Ι
Κάτοχος Μεταπτυχιακού Τίτλου

Δ.4. ***Ασχολείστε Επαγγελματικά με κάποιο από τα παρακάτω πεδία;***

Την Τοπογραφία - Χαρτογραφία	Ναι	Όχι
Τα Γεωγραφικά Συστήματα Πληροφοριών	Ναι	Όχι
Τη Γεωγραφία	Ναι	Όχι

Δ.5. ***Που κατοικείτε;***

Αθήνα	
Θεσσαλονίκη	
Αλλού (Προσδιορίστε: …………………….)	

APPENDIX II

Brief curriculum vitae

1.1. Education

2010-2015: Ph.D. student, School of Rural and Surveying Engineering, NTUA (National Technical University of Athens), Greece.

Doctoral Thesis: "The Volunteered Geographic Information in Land Administration: Crowdsourcing Techniques in Cadastral Surveys". Supervisor: Ass. Prof. Chryssy Potsiou

(The research was funded by the Greek State Scholarships Foundation).

2008- 2009: MSc in GIS (Geographic Information Science), Department of Civil and Geomatic Enginnering, UCL, (University, College, London), United Kingdom.

Dissertation Thesis: "Evaluation of the OpenStreetMap quality", Supervisor: Prof. M.M. Haklay.

Grade: 2:1 Upper Second-Class Honours

2003-2008: BSc in Rural and Surveying Engineering, NTUA (National Technical University of Athens), Greece.

Dissertation thesis: "The expropriation process in Greece and implementaion in three main motorways". Supervisor: Ass. Prof. Chryssy Potsiou.

Grade: 7.94 / 10 (4th out of 95 graduated students of 2008)

1991-2003: Arsakeio School in Psychico, Primary, Secondary Education and General Lyceum (High School)

Grade: 18.6/20 (Award by the Ministry of Education for High School academic excellence)

1.2. Employment record

2011 – Currently: Public Assets Team Leader – Surveyor Engineer, Archaeological Cadastre, Ministry of Culture and Athletes (http://archaeocadastre.culture.gr/)

Duties: Registration of attribute and spatial data of the public assets in Open Source Software Systems with specialization in the expropriations' process. Geographical localization of public parcels on LSO and topographic surveys. Technical documentation of different manners of acquisition of the public assets and connectivity to the cultural heritage.

2011 – Currently: Laboratory Support Staff, School of Rural and Surveying Engineering, NTUA (National Technical University of Athens), Athens, Greece

Duties: Laboratory Support Staff and assistant teaching in three undergraduate modules; “Cadastre”, “Cadastre and GIS”, “Cadastral Systems and Land Administration”.

2014 – Currently: Affiliated Staff, ExSites (interdisciplinary Extreme Citizen Science research group under the supervision of Professor M.M. Haklay), UCL, London, United Kingdom

2009 – Currently: Freelance Surveyor Engineer

Duties: GIS applications, Topographic Surveys.

1.3. Research Activity

02’ – 03’ 2014: Short term scientific mission, “Citizen Mappers in Volunteered Cadastral Projects”, Extreme Citizen Science research group, Prof. M.M. Haklay, UCL (University College London), London, United Kingdom.

2011 – Currently: MC Member of the IC 1203 ENERGIC COST ACTION (European Network Exploring Research into Geospatial Information Crowdsourcing): software and methodologies for harnessing geographic information from the crowd.

1.4. Publications in scientific Journals and Books

Basiouka, S., Potsiou, C., 2015. “A Proposed Crowdsourcing Cadastral Model: Taking Advantage of Previous Experience and Innovative Techniques”. ENERGIC book IC 1203 COST ACTION (under publication).

Basiouka, S., Potsiou, C., & Bakogiannis, E. 2015. “OpenStreetMap for cadastral purposes: an application using VGI for official processes in urban areas”. *Survey Review*, 1752270615Y-0000000011.

Haklay, M., Antoniou, V., **Basiouka, S.**, Soden, R., and Mooney, P. 2014. “Crowdsourced geographic information use in government”, Report to GFDRR (World Bank). London.

Basiouka, S., Potsiou, C., 2013. “The Volunteered Geographic Information in Cadastre: perspectives and citizens’ motivations over potential participation in mapping” *GeoJournal,* vol. 79(**3**), 343-355.

Sylaiou, S., **Basiouka, S.,** Patias, P., Stylianidis, S., 2013. “The Volunteered Geographic Information in Archaeology” ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume II-5/W1, pp.301-306. [The paper has been awarded a prize in academic year 2013 from Thomaidio Bequest as a result of the competition entitled “Thomaidia Awards for the Progress of Science and Art”].

Sylaiou, S., **Basiouka, S.**, Potsiou, C., Patias, P., 2012. “Inspection of VGI applications in Cultural Heritage”. Horografies Journal, vol. 3, ar. 1, pp. 15 – 22 ISSN 1792-3913 (in Greek).

Basiouka, S., Potsiou, C., 2012. “VGI in Cadastre: a Greek experiment to investigate the potential of crowd sourcing techniques in Cadastral Mapping”. *Survey Review*, vol. 44 (325), April, 2012, pp. 153-161(9). [The paper has been awarded a prize in academic year 2012 from Thomaidio Bequest as a result of the competition entitled “Thomaidia Awards for the Progress of Science and Art”].

Potsiou, C., **Basiouka, S.**, 2012. “Security of ownership versus public benefit: a case study for land taking for infrastructure in Greece, as an EU member state”. *Survey Review*, vol. 44 (325), April, 2012, pp. 111-123(13).

Basiouka, S., Potsiou, C., 2012. “Improving cadastral survey procedures using crowd sourcing techniques”. *Coordinates Magazine*, vol. VIII, issue 10, October 2012

Kounadi, O., **Basiouka, S.,** 2010, “The phenomenon of Volunteered Geographic Information Science; The OpenstreetMap example in Athens and London”. Aeihoros Journal 14, Special Issue, November 2010, pp 64 – 93 (in Greek).

Haklay, M., **Basiouka, S.,** Antoniou, V., Ather, A., 2010. “How many volunteers does it take to map an area well? The Validity of Linus' Law to Volunteered Geographic Information” *The Cartographic Journal,* vol. 47 (4), November 2010, pp. 315-322(8).

1.5. Publications in international conferences

Basiouka, S., Potsiou, C., Bakoyiannis, E., 2014. “The OpenStreetMap For Cadastral Purposes: An Application Using VGI For Official Processes In Urban Areas”. *Proceedings (CD) of the FIG Commission 3 Workshop on “Geospatial Crowdsourcing and VGI: Establishment of SDI & SIM”,* 4-7 November, Bologna, Italy. [The paper was awarded as Best Workshop Paper by the FIG Commission 3].

Basiouka, S., 2014**. “**Citizen Mappers in Volunteered Cadastral Projects”, *Proceedings of the 3ed Citizen CyberScience Summit*, 20-22 February, London, United Kingdom.

Sylaiou, S., **Basiouka, S.,** Patias, P., Stylianidis, S., 2013. “The Volunteered Geographic Information in Archaeology”, CIPA 2013 Symposium, Recording, Documentation and Cooperation for Cultural Heritage, XXIV International CIPA Symposium, 02 – 06 September, Strasbourg, France.

Basiouka, S., Potsiou, C., 2012. “Citizens’ Motivations for introducing Crowdsourcing in the Cadastral Procedure”,. *Proceedings (CD) of the FIG Commission 3 και UN ECE/WPLA Workshop on “Informal Development, Property and Housing”*, 10-14 December, Athens, Greece.

Yiouroussis, A., Vavouranakis, G., Vradis, C., **Basiouka, S.,** Sylaiou, S., 2012. “ Archaeological Cadastre ”, *Proceedings (CD) of the 7th HellasGIs Conference,* 17 – 18 May, Athens, Greece.

Basiouka, S., Potsiou, C., 2012. “The Voluntary Contribution of Citizens in Cadastre. Crowdsourcing in Cadastre”, *Proceedings (CD) of the FIG Working Week on “Knowing to* *manage the territory, protect the environment, evaluate the cultural heritage",* 06 – 10 May, Rome, Italy.

Potsiou, C., **Basiouka, S**., 2012. "The Use of Volunteered Geospatial Information and crowd sourcing techniques to improve cadastral survey procedures", *Proceedings (CD) of the Annual World Bank Conference on Land and Poverty,* 23 – 26 April, Washington D.C. U.S.A.

Basiouka, S., Potsiou, C., 2011. "A First Attempt for Using Volunteered Geographic Information and Crowd Sourcing Techniques in Cadastre" *Proceedings (CD) of the FIG Commission 3 Workshop on "The Empowerment of Local Authorities: Spatial Information and Spatial Planning Tools",* 24 – 28 October, Paris, France

Demetriou, G., **Basiouka, S.,** Potsiou, C., Hanos, M., 2010. "Expropriations and New Motorways; Necessary Improvements of expropriations' procedures in combination to cadastral process". *Proceedings (CD) of the 3nd Hellenic Conference of Rural and Surveyor Engineers,* 17 – 18 December, Athens, Greece.

Kounadi, O., **Basiouka, S.,** 2010, "The phenomenon of Volunteered Geographic Information Science; The OpenstreetMap example in Athens and London". *Proceedings (CD) of the 6th HellasGIs Conference,* 02 – 03 December, Athens, Greece.

Potsiou, C., **Basiouka, S.**, 2010. "Land expropriation in Greece. A case study for Road Networks" *Proceedings (CD) of the FIG Commission 3 Annual Meeting on "Information and Land Management. A Decade after the Millennium",* 14 – 17 November, Sofia, Bulgaria. [The presentation has been awarded a prize in academic year 2010 from Thomaidio Bequest as a result of the competition entitled "Thomaidia Awards for the Progress of Science and Art"].

Basiouka, S., 2010. "The use of dynamic maps and Volunteered Geographic Information in Greece" *Proceedings (CD) of the FIG Commission 3 Annual Meeting on "Information and Land Management. A Decade after the Millennium"*, 14 – 17 November, Sofia, Bulgaria.

Haklay, M., Ather, A., **Basiouka, S**., 2010. "How many volunteers does it take to map an area well?" *Proceedings of the GIS Research UK 18th Annual Conference GISRUK 2010,* 14 – 16 April, London, UK.