Multi-Dimensional Land Management Systems: A Delphi Study of the Expert Community

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SUMMARY

Multi-purpose and multi-dimensional land management systems (MMLMS) are extremely demanded for sustainable management of land resources. New urban trends are emerging, such as 18-hour city and urbanization processes, which clearly influence land planning and construction. Stakeholders from different backgrounds and various field reshape the current and future status of cities and take part, directly or indirectly, in related decision-making. These encourage creating one common land management system that serve the various-end users who affect managing land property, such system is expected to save unnecessary work, efforts and resources, to enable cooperation and coordination in one platform and to accelerate planning, registration and construction processes. The aspired land management systems (LMS) have to be multi-dimensional in order to satisfy: the increasing population and density in urban areas - which resulted in vertical construction above and below ground-, the accelerating changes in land properties and real estate, the needs of different experts who work with LMS for various purposes and applications. Thus, the system should include five dimensions: plane (2D), height, time and Levels of Details (LODs). Since no working MMLMS exist yet, but rather it would be created in accordance with the perspective of potential stakeholders and experts from different fields and would be influenced by future trends, we pursued Delphi approach, in which we disseminated a questionnaire, constituted from open-end questions, upon experts engaged in land use, and they were asked to answer two categories of questions. First category included theoretical questions, focusing on semantic and mathematical definitions; the second category included technical questions, focusing on functionalities, databases, data collection, etc. Based on the responses, we suggest guidelines for creating data models in a MMLMS and emphasize main issues and results.

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1. INTRODUCTION

With the population rapid grow, land resources are becoming scarcer and valuable, requiring complex and dense urban planning, which coerce the overlapping and integration of structure arrangements in space. This, in turn, enforce an efficient usage of the built environment, meaning that perspectives for utilizing vertical land resources, among others, need to be made. Multi-dimensional Land Management Systems (MLMS) are developed for achieving, handling and analyzing the restrictions, responsibilities and rights (RRR) of land properties in space, time and different levels of detail. Accordingly, advanced multi-purpose sustainable MLMS are crucial to significantly contribute to current space and time built environment demands, as well as serve various end-users, to allow diverse and rich services.

Current research on MLMS mostly put emphasize on technical aspects, e.g., database and visualization. Mapping the functionalities and fundamentals of MLMS is hardly addressed, where the clear purpose and design of these systems, in terms of services they should provide to the various end-users, are still required. Critical questions and change of ideas that will serve as working grounds are still not fully formalized in defining the perceptions of the involved parties - the expert community, where various system definitions should be carefully illustrated.

It is vital to understand the experts perspective regarding the systems fundamentals, and to qualitatively asses their needs and expectations from a functional MLMS. It is also important to realize and model emerging and influential technological trends in land management that directly affect land resources. For this purpose, we designed a Delphi study, that is an iterative questionnaire addressed to the experts community, for investigating and understating their requirements and expectations from MLMS. The experts that participated in this study include real estate, urban planning, transportation, cadaster and geodesy. The study's questions are written in a manner that does not guide the participants to a specific answer, but rather in a way that enables inferring as much information as possible. The questions are categorized under two groups: 1) semantic, theoretical and mathematical definitions focusing on the contributions, importance, and practicalities of MLMS (for example: "How many dimensions are needed for describing temporal changes?" to understand whether time should not be handled as a single dimension, since it may represent several change types, e.g., geometrical, topological and thematic); 2) questions related to data management, e.g., data structure and data model, functionalities and processes, data collection, accuracy, and visualization.

This paper presents the outcome of this Delphi study, and the general guidelines that should be considered for incorporation when formalizing MLMS and its various applications. Results show that integrating temporal and scale aspects in MLMS need to be analyzed and well formalized beforehand. Our Delphi study firstly specifies the disciplines that use MLMSs, and their methods they will use them. According to these, our paper will outline the recommendations for formalization long-term aspects required in an applicative MLMS, which will serve various experts and users from various fields having different needs. These will include, among others, data structure, processes and functionalities that are related to all dimensions.

2. LITERATURE REVIEW

Previous research tried to understand the perceptions, predictions and future of land administration domain based on experts' opinion, such as Krigsholm et al., 2017, Krigsholm et al., 2018, Halim et al., 2017, Bohman et al., 2019. Some have implemented the Delphi technique in land management research, such as Krigsholm, et al., 2017, and Halim, et al., 2017. Krigsholm, et al., 2017, conducted a two-round Delphi study for investigating the effect of specific megatrends on the Finnish cadastral system. According to the participants' perspective, the Finnish cadastral system would be shaped by future technological developments and it would be mostly influenced by the megatrends of digital culture, ubiquitous intelligence, and a tendency towards transparency, accessibility, and open data. Other megatrends were examined in the study, but not identified as the most influencing, including urbanization, business ecosystem, new patterns of mobility, global risk society, knowledge-based economy.

For defining the importance of National Digital Cadastral Database (NDCDB) of Malaysia, Halim, et al., 2017, reviewed 14 experts from different backgrounds aiming at gaining consensus on specific statements regarding the future of NDCDB. After 3 rounds, a consensus on 7 statements was gained implying the importance of NDCDB role in Malaysia for spatially enabled society and government - as well as for sustainable decision-making and development. The statements in the study were also connected to disaster analysis, expressing the significant role of NDCDB for enabling accurate land-based analysis and results in different domains including disaster management and post-disaster effects analysis. "Both disaster management and sustainable development require sound land governance to reduce the impacts of climate change and post-disaster effects" (Ujang, 2017; Halim, et al., 2017).

Bohman et al., 2019, presents a web-based visualization tool for exploring stakeholders' conflicts in land-use planning, with the purpose of examining the contribution of web technologies for enabling users to share and discuss their perspectives regarding land use planning and decision-making. According to the authors, such tools increase democracy by enabling relative stakeholders to express their point of views in land-use planning and urban development. These researches prove the importance of creating an LMS compatible with current and future needs for practical and applicable situations, reflecting the contribution of collaborative work among different experts in the same system designed for society benefit.

3. METHODOLOGY

This study aims at putting guidelines for creating data model in MMLMS based on the needs of stakeholders and end-users of the system. For that intention, we point the main purposes of MMLMS, then we define end-users and experts who may utilize MMLMS. Next, a summary of the structure of our Delphi questionnaire is given. Followed by the main findings we concluded from first round of the study.

3.1 The purpose of MMLMS: why multi-purpose and multi-dimensional LMS?

Respondents agreed that for sustainable management of land, multi-purpose systems must exist enabling cooperation between different authorities and end users which are involved in common practical processes in order to eliminate constitutional and jurisdictional delays and enable seamless flow of projects. For example, interaction between planning and registration is inevitable, as depicted in Fig 1, where the interaction between different end-users and professions exists also in conventional actions that must be performed before a construction starts. This example shows that a common database, that various users share, in one shared system may assist in solving planning problems and enable better sharing and utilizing of data.

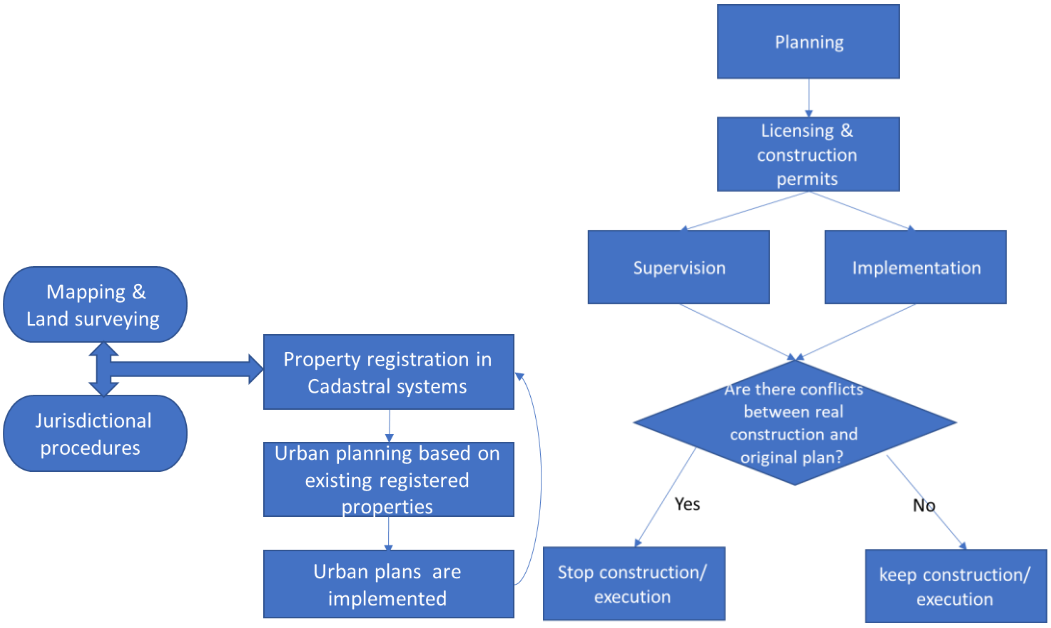

Fig 1: Processes demonstrate the cruciality of cooperation between various stakeholders.

3.2 The functionality and significance of MMLMS

Various fields are related to land resources, such as: cadaster and land registration, real estate and housing, urban planning and construction, transportation, geodesy, emergency services, energy optimizing and shadow tracking. An optimal MMLMS should provide functionalities for serving as many as possible end-users; thus, enable collaboration, coordination and sharing data for sustainable and effective management of land resources. The role of the 5th dimension is obvious: it is required for presenting fit-for-purpose data, in different LODs and scales. Adding the 4th dimension is expected to assist in monitoring urban changes and cultural heritage, tracking past urban trends and human mobility and expecting future trends. These would contribute to a better urban planning that keeps resources for future generations and to effective management of rights, restrictions and responsibilities (RRR) that change as a function of time.

3.3 The users' needs

After defining the purpose, we needed to choose participants thoroughly. Criteria for choosing experts were suggested in previous literature. Among the criteria, is to choose participants who are not too close to the problem, since experts involved in a specific topic might not be capable to have an overall view of the problem and the future suitability (Fortune, 1992). Cultural biases may also affect Delphi study, as investigated in Scholl et al., 2004, and Dalkey, 1972. Accordingly, this stimulated us to select experts from different states in the world. For investigating the future of electric vehicles, for example, Warth et al., 2013, applied four criteria for selecting experts to be interviewed, including: " (1)knowledge and experience of the issues under investigation; (2) capacity and willingness to participate; (3) sufficient time to participate; (4) effective communication skills". Thus, experts should have at least a basic knowledge but preferably not too close to the investigated problem. Our participants were heterogeneously chosen, including: urban planners, land appraisal, spatial analysts, municipalities engineer, experts in Geographic Information Systems (GIS), cadastral researchers, etc. The purpose of the study should be well clarified to the participants in order to keep their interest, while preventing irrelevant replies (Yousuf, 2007). In the beginning of our questionnaire, the purposes and expectations were fully declared. According to the above, general applications and benefits that might be enabled by MMLMS were categorized, as depicted in Table 1.

Urban Planning	Dynamic Rights and Restrictions	Technical aspects	Applications
Historical archiving	Leases	Full reference to space, time and scale	Multi-purpose applications
Cultural heritage	Season dependencies	Integrated database	Decision making
Urban development trends	Natural dynamic objects	5D search	Costs and effectiveness
Human mobility			
Changes in land use/land cover			

Table 1: The benefits and functionalities prompted by the MMLMS.

3.4 Cultural considerations

Cultural considerations should be also investigated, since legislations, land values, and technological accessibility differ from state to state, directly affecting the MMLMS. In future study, this aspect will be investigated.

3.5 Questionnaire

Relevant experts received a message explaining the aims of our study and inviting them to take part and contribute to this research. The importance of their participation was established and well emphasized. Participants were asked to provide information about their specialization field, years of experience, education and technical skills that they earned. After that, they were asked to answer two categories of questions. First category included theoretical questions, focusing on semantic and mathematical definitions; second category included technical questions, focusing on functionalities, databases, data collection, etc. We provide sample questions from our Delphi study:

3.5.1 First category

1. How would you define the time dimension within an LMS context? What should it serve? How should the time be archived/managed in the system?
2. How would you define the scale dimension within an LMS context? What should it serve? How should the scale be archived/managed in the system?
3. In urban areas, changes in real estate might be continuous because they occur all the time. Do you think it is necessary to continuously update the LMS - or not? What is the efficient rate (epoch) for updating the system? Should this rate be time-dependent? Or should it be based on the range of the physical changes that occur (e.g., transactions, physical and geometric changes, such as construction or destruction, new land use plans, changes in property value and ownership transfer, etc.)?

3.5.2 Second category

1. What would be the optimal way of storing and systematically managing continues changes that will serve your purposes? Examples: For the purpose of "monitoring of various landscape changes over the last 50+ years", (Nebiker et al., 2014) suggests using dense image matching and object-based image analysis for creating change detections based on greyscale and color aerial photographs.
2. Can you name any measures and tests that should be made for determining whether LMS should be integrated (scale and time and space) – or divided into two sub-systems? Please think of processes, functions and algorithms that might be required in LMS for serving your field; Is it important to use temporal data and various scales simultaneously for applying those algorithms - or not?
3. Which are the most common and important 3D queries needed to be performed in land management systems in your opinion (for managing spatial objects)? Please give examples of 4D (for managing time dimension and time-based changes) and 5D (for describing the space in different scales) queries that you would you require from such system? Examples: 3D - Find all the buildings that exist in a given radius and calculate their volume. 4D - Calculate the rate of density growth over the last ten years.

4. FINDINGS BASED ON THE DELPHI SURVEY

4.1 Data structure

4.1.1 Time attribute:

To the best of our knowledge, time dimension was included indirectly in databases. For example, in a cadastral database, a user can search for plans according to the date when they were approved, building permissions can be also presented according the advocating dates. However, no time attribute explicitly exists in geoinformation systems. In future LMS, each entity in the data structure would have additional fields indicating the time span of its validity, i.e. the time span when the entity practically (physically) existed depicted by start and end time. Additional begin and end dates would be supplied, indicating the time when the entity was legally registered.

4.1.2 Time attribute importance:

Urban renewal or urban regeneration (UK) or urban redevelopment (USA) result in, among others, changes of ownerships and owners; more sub-parcels are created as a result of such projects, the configuration of neighborhoods alters, land uses vary, etc. Usually, it takes a long time before those changes are registered in digital systems. Urban renewal is among the main trends that invoke adding the time attribute and historical archives.

4.1.3 Historical data about previous ownerships:

An example of data required for research and analysis in urban planning and urban renewal projects, include information regarding previous ownerships for analyzing the reasons that caused them to leave a specific neighborhood. Such information is of big importance from the perspective of urban planners but cannot be easily accessed. Databases for relevant authorities lack such data, or include it partially and disorderly. Historical list of owners would be linked to apartments.

4.1.4 Event-based vs. state-based:

In a state-based model, the results are modelled explicitly: every object gets (at least) two dates/times. In event-based model, transactions are modelled as separate entities within the system. Participants were asked whether they would find an event-based model more practical and recommended than a state-based model for managing 4D LMS. Responses on these questions varied among urban planners (whether they work in academy, government sectors or jurisdictional institutions), municipality engineers and workers in facility and infrastructure expressed that they are less interested in knowing when, for example, a building permit was submitted, how long it took to approve it, the number of building permits granted versus the amount of time it took to discuss permit applications, etc. From their perspective, a state-based model is more relevant to the planning process. Important information may exist in the databases, but not always relevant for planning and planners, such as when was a plan approved or information on relevant protocols. Time and date attributes might not be necessary in this case for urban planners, but rather current state is more important - that is why they preferred state-based models. Respondents from different fields expressed that grasping the reality is much more intuitive and easier in state-based models. Besides, state-based models may require additional queries for accessing specific object. However, there are cases when state-based is required for tracking and querying transactions. An optimal database is one that enables switching between event-based model and state-based model, dependent on the needed application. Fewer number of experts, from land administration and cadaster, preferred event-based models but did not illustrate the reason of this preference. Those respondents digitally answered this question, which was formulated in a way that asks to choose one option: either state or event-based model; and could not express their desire to use both. To sum up, the preferable approach in MMLMS depends on the needs of the end-users, planners or otherwise. This leads to next topic: transactions vs. objects.

4.1.5 Transactions vs. Objects:

Both are essential for planning and for information accessibility, but each is more acute for specific purposes and implementations. For example, someone who wants to buy an apartment may be interested in identifying the previous owners and the previous deals that took place. However, urban planners are less interested in previous transactions, but more focused on the current state and existing entities in the neighborhood they are planning. An example of a conventional transaction in land registration is expropriation, which is usually linked to specific parcels, Fig 3 shows suggested fields and methods in "Transaction" and "Expropriation" classes. In this context, the question of whether transactions should be linked to objects in databases (Fig 2), or should they be separated, is raised. From the one side, separating these classes is rational and more effective for somebody who search objects only and prefer to review segmented information according to specific query. From the other side, separation might not be always possible. This was a point of disagreement, and in the next iteration, we will try to get a consensus on this topic.

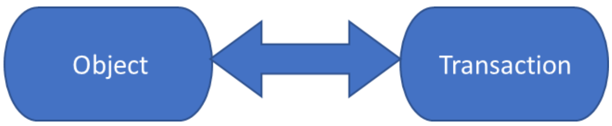

Fig 2. The “Transaction” class should be linked to objects.

Transaction
TransactionDate TransactionPurpose
AddFieldsToExpropriation GetFields ReadFromCAD

Expropriation
DepositingDate ExecutionDate ParcelsNumber ExpropriationPurpose ExpropriationPercentage CummulativePercentage
AddFieldsToExpropriation GetFields ReadFromCAD

Fig. 3. Suggested fields and methods in "Expropriation" and "Transaction" classes.

4.1.6 Semantic vs. geometric attributes:

A proper data model should relate to both semantic and geometric attributes, as both types could be dynamic and within multiple scales. Forests, water bodies, countries changing boundaries, parcel boundaries in areas prone to earthquakes are examples of objects with dynamic boundaries. Classes representing such objects should offer a list of historical boundaries of each object, a dynamic geometric attribute, so that the system would be able to visualize previous boundaries. In addition, boundaries' accuracy depends on the legacy of specific state and the land value. In states with very expensive land resources, the resolution of inserting data to the system should be high, while in states where land are less expensive, lower resolutions might be sufficient. In other words, the legislative and semantic attributes are necessary as they affect the required scale of data, i.e. the 5^{th} dimension.

4.2 Data accessibility

Transparent governments already exist in many states in the world (e.g., the UK and the US) and share information with citizens. Usually, authorities with more money provide more information. In Israel, for example, "abstracts of titles" and "land registration extracts" can be accessed through the Justice Department, usually lacking ownership data layers and attributes. "Historical extracts" provide data about all previous owners of a particular building, such data is important for planning since it is necessary to know who owned a specific building in the past (that reflects the importance of the time dimension). However, the information on "historical extracts" is not spatially presented, and they are usually registered in lists only. Besides, significant amount of money should be paid for getting that information - which is protected information. The state earns the money for data collecting and maintenance, for enabling "accessibility of information" and for solving technical and personnel problems. As stated above, in urban planning field, recognizing the owners is vital. Their identity is required for obtaining their consents on new plans, even in cases when a new plan does not directly intersect their properties, but rather it is near their parcels, they should be notified according to the Planning and Construction Law before implementing the new plan. Ownership attribute is crucial for planning, still, this attribute can be digitally accessed only through databases of jurisdictional institutions and not through planning institutions databases. This fact invokes collaborative work between different parties and working within common system for accessing data and providing additional attributes.

4.3 Data sources and accuracy

VGI and crowdsourcing were proposed as data sources for enriching MMLMS. Experts' opinion on this issue was required. Respondents believe that crowdsourcing data is a complementary data that could be used; however it cannot be trusted to be a major primary data source, so such sources will still be - probably for the years to come - secondary data sources and will complement any other traditional or conventional data source, such as photogrammetry and LiDAR. VGI and crowdsourcing cannot be fully trusted at this stage, since data contributors still lack the maturity and responsibility to provide accurate and reliable data. Others say VGI could be used as a primary source even if less precise, in cases where the value of land is considered: if the land value is not expensive, then less accurate data would be sufficient, whereas in states where land is very valuable, every cm^2 makes difference, and VGI might not be a good data resource. In other words, whether to use VGI or not depends on regulations of a specific state, the demanded accuracy of projects and the scale of data presentation, which again brings up the importance of semantic attributes. Besides, validation processes should be conducted when VGI is used.

4.4 Sample queries and processes

For detecting the required sample queries, the applicants of LMS should be first identified, arranged and listed. However, there are sample queries that respondents agree on their cruciality. For instance, a query enabling identifying the owners of particular buildings in specific zoning plans is required for effective estate management. An additional example, is a query enabling analyzing and modeling buildings' shadows along the day, demanded in MMLMS that enable visualization. Typical processes in regular LMS include searching and presenting land parcels within a given area in a given time span and in different LODs; inserting a new parcel to the database; presenting dates of leases, title registration, approved boundary plans, etc.

5. CONCLUSIONS

Current land needs, rapid population growth and contemporary urban trends require wise management of land resources, in which sustainability and collaboration are important values. For that, the perspectives of experts involved in land management, from different fields, are required since they all influence land resources. This reason encouraged us to implement Delphi study, in which we try to reveal varying prospects and utilize them to suggest data models in MMLMS. The challenge is to identify the specific needs of different end-users of MMLMS, their preferences, and the functions they expect to receive from MMLMS. This research is an attempt to get ‘closer to the truth’, to define the common issues from all the varying responds, to find common solution based on experts' recommendations and to extract guiding directions for structuring MMLMS. The main objective is to gain knowledge regarding the optimal data model, based on sought consensus among experts. For that purpose, other rounds are still required. The fact that no operational MMLMS exist in the world today, and that this problem is still unsolved, the diversity of experts and end-users, the ambition to identify future trends affecting land management and resources are additional motives for pursuing Delphi approach.

To the best of our knowledge, this is among the few studies that implement Delphi technique for setting suitable data model in MLMS. In this paper, recommendations related to data structure, required processes and queries in MMLMS were suggested, data accessibility and data sources were also discussed. The main conclusion we inferred relates to the significance of developing functioning MMLMS especially for accelerating sustainable planning and construction projects without unnecessary administrative delays. Disagreements on suitable data source emerged, emphasizing that cultural and legal considerations in specific state should determine the way of gathering multi-dimensional data. Required data accuracy, land value and the circumstances of a nation should also be considered. These may serve for directing the upcoming urban development in a sustainable manner that will preserve natural resources for future ages. Time element will enable monitoring boundaries and ownership changes, dynamic objects in general, especially natural objects (e.g., shoreline), as well as rights and restriction that could be time-dependent, such as leases and season dependencies (grazing, gathering vegetation, hunting/fishing, etc.). These may serve for directing the upcoming urban development in a sustainable manner that will preserve natural resources for future ages.

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