URBAN INFORMATION MODEL FOR CITY PLANNING

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SUMMARY: *City planning is a complex task and therefore needs to consider the interplay between multi-aspects of a city, for example, transport, pollution, and crime. A city model is important to representing urban issues in a clear manner to the relative stakeholders. Although some city models have been used in the planning process, they are often based on narrow data sets. When sustainability and the quality of urban life generally is considered a more holistic analysis of city issues during the planning process is needed. It calls for city models to be based on integrated data sets. The paper describes the concept and challenges of nD urban information model. The research work on how to develop an nD urban information model to accommodate data sets relevant to different aspects of city planning is presented.*

KEYWORD: *data model, interoperability, integration metadata, nD model*

1. INTRODUCTION

Cities are dynamic living organisms that are evolving through interplay of regulatory and entrepreneurial activities. Thus city planning has always been difficult. Today our rapidly changing society makes the job of predicting future needs of city dwellers, and those who depend on the services cities provide, even more problematic. Particular problems include: transport, pollution, crime, conservation and economic regeneration. In addressing the complexities of city planning it is important to consider the physical structure of the city alongside less tangible economic, social, environmental and cultural factors. Current thinking emphasises solutions which take a holistic view of both the future sustainability, as identified in Agenda 21, and cultural heritage of cities (Hamilton 2001).

Those involved in the sophisticated art of city planning use a variety of tools. These already include city models. It is evident from a review of city models, that systems based on a narrow data sets concerning only one topic, e.g. transport, have limited use (Hamilton 1998).

In recent years more work has been devoted to the integration of urban data sets. In particular the EU funded FP integration project ‘Intelcities’ aims to produce integrated and interoperable city systems. The Intelcities vision is illustrated in Fig. 1.

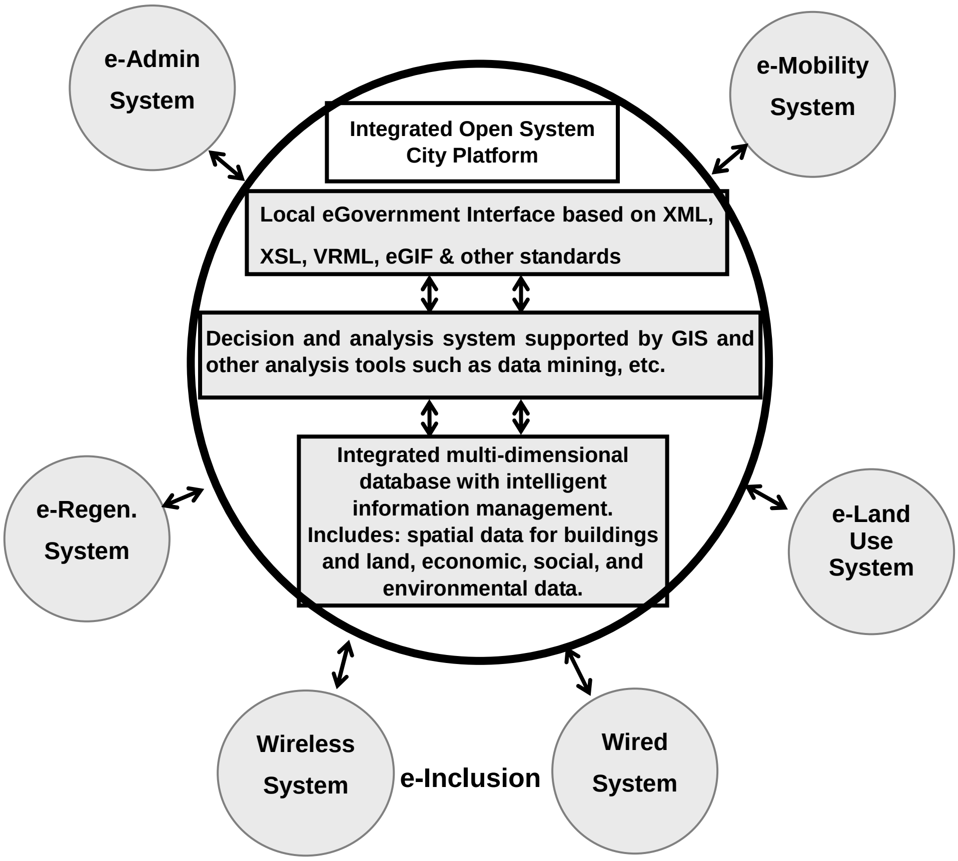

FIG.1: ICT functionalities to deliver an Integrated Open System City Platform (IOSCP)

One objective of the Intelcities project is to build up an integrated system for e-Governance. The key problem facing the project is developing an Integrated Open System City Platform (IOSCP) i.e. ‘e-City Platform’ which the e-Governance systems can be built upon. It is clear to be seen from Figure 1 that “Integrated multi-dimensional database with intelligent information management. Includes: spatial data for buildings and land, economic, social, and environmental data” is the fundamental base for this e-City Platform. This multi-source data should provide the support for various urban datasets integration and implement the information interoperability based on current e-GIF (e-Government Interoperability Framework)(e-GIF 2004) and other data standards. In order to facilitate this, several Intelcities partners are engaged in the integration of 3D spatial information with other data sets. This forms the main theme for this paper.

It is useful to review recent work in integrating 3D and other data sets. It is possible to bring together the traditional GIS and VR products in order to use VR to present geo-spatial data in a virtual environment (Song 2003). However, using these approaches, the data can be represented through VR only in a 2.5D view, not a full 3D view. This is because the data structures of current commercial GIS do not have the capability to store information to present a full 3D view. Only the vertices of a map object, such as a polygon, and one particular attribute value, such as ‘height’, can be used to generate the 3D object. This limits the VR view so that it is not ‘attractive’. In the other words, geo-objects cannot be represented in detail, such as the inner skin of a building.

Many developers have used a CAD model library, storing full 3D information of geo-objects, to spatially reference with a GIS map object to achieve a full 3D view. This entails the extra task of database maintenance, for data consistency and integrity. Since GIS data is continually being changed, the linkage between the geo-spatial data and the VR model library could become invalid after an object has been modified, or deleted, in the

GIS application.

Efforts are being made in the industry to provide a better solution to achieving full 3D virtual environments, using an improved geo-spatial data storage structure and a spatial-based data query language (Spatial SQL). Attribute data, 2D spatial data and 3D data could be organized in one single database to enable any kind of client to access GI data freely. Numerous industry database groups, such as Oracle, are contributing to this.

An important factor in building up a holistic urban data model is the use of data sets originally produced for other purposes. Thus city data can be procured from information originally gathered for building purposes. In a physical sense a city is a collection of buildings. In the construction industry the push for business improvement processes has resulted an interest in integrated data models.

A construction industry shift has been called to bring more consideration of different, sometimes conflicting, factors into building design process (Barrett 2003). It supports current initiatives by government, industry and clients intended to bring substantial improvements to the performance of building industry and its products(Egan 1998). In the wake of the initiatives, the nD modeling research agenda is looking at how information technology can help to improve the efficiency and effectiveness of the building design and construction process (Lee 2003).

The movement of construction industry has been followed increasing interest in urban issues. In the urban planning process, a comprehensive and integrated vision is needed which leads to the resolution of urban problems and seeks to bring about a lasting improvement in the economic, physical, social and environmental condition of the target area.

Although focusing on different scales of built and human environment, building design and urban planning have some similar characteristics; they are, for example, multi-dimensional and complex. Therefore they face similar challenges in their decision-making process which is the integration of multi-dimensional information and comparisons of different design/planning alternatives. This is discussed elsewhere in this special edition – ref to HyCon paper. The Research Institute for the Built and Human Environment (BuHu), at University of Salford, UK, is addressing these challenges at both the building and urban scale.

The paper aims at explaining the ongoing research in BuHu concerning developing a concept nD model to illustrate how data can be integrated to develop a data framework to support intelligent city systems.

The paper starts with explaining the concept of a holistic nD urban information model. Then the challenges of an nD urban model are described. It then leads to current work within Intelcities on how to use data modeling approach to develop nD urban database. Several issues are addressed regarding to the integration methodology and interoperability strategy. The paper concludes with a briefing of the findings in the research and highlights the issues for future development.

2. nD URBAN INFORMATION MODELLING FOR PLANNING

The concept of nD urban information models discussed in this paper are influenced by UK EPSRC funded 3D to nD modelling research project (Lee 2003), which aims to develop the infrastructure, methodologies and technologies that will facilitate the integration of time, cost, accessibility, sustainability, maintainability, acoustics, crime, and thermal requirements with 3D building model. The nD model could be seen as an extension of the building information model by incorporating all the design information required at each stage of the lifecycle of a building facility (Lee 2003). We extend this concept into much complex urban environment.

2.1 Why Do We Need nD Modelling in Urban Planning?

As noted in the introduction and elsewhere urban planning is complex(Hamilton 2001). The decision making of urban planning needs to consider the physical structure of the city along with economic, social and environmental factors. The urban planning process has now been enhanced by various IT tools. Information Technology has certainly brought significant improvements to the speed and cost of capturing and maintaining data. But our ability to manage and make efficient use of this information leaves much to be desired.

Currently, GIS software is one of the mostly accepted IT applications used in this process. GIS is particularly useful for the generation of descriptive and prescriptive information: the analysis of the present state of the planning area and the evaluation of scenarios for future development (Webster 1993; Webster 1994). Existing GIS tools are good at handling the vector and raster formatted data used at the urban scale. However, general

GIS no longer satisfies the multitude of visualisation demands due to the lack of 3D detail information.

Visualization can aid the communication and collaboration among many participants during the problem solving and decision making of urban planning(Langendorf 2001). With the rapid development of computer hardware and VR techniques, 3D urban scenes need to be visualized and simulated interactively. Wang and Hamilton(Wang 2004a) listed five popular 3D modelling methods: CAD modeling; GIS-based modelling, Image-based modelling, LiDAR modelling and Panorama photographs model method. Due to the complexity of 3D urban environment and heterogeneity of various data sources, 3D urban model are still at developing stage. Lots of research works are carried on how to effectively manage 3D urban model (Chan, Jepson et al. 1998; Wasilewski, Faust et al. 1999; Zlatanova and Tempfli 2000; Kolbe and Gröger 2003).

Using such advanced software applications helps stakeholders to make decisions in the planning process. However, taking effective decisions in urban planning requires more than the presentation of the graphical information. Parties need to assess the quality of the environment from different perspectives.

Urban information is always related with temporal dimension. Planning is about creating ideas and plans which will inform the future. The design of solutions to planning problems deal not only simply with present data but also with past and future data(Harris and Batty 1993). Presenting the temporal dimension is complicated. GIS are not well adapted to dealing with temporal data. Few integrated approaches exist that can treat the spatial-temporal data in a unified manner(Raza 2001).

Further more, City have economic, social and environmental attributes besides spatial and temporal dimensions. Urban planning has to address theses factors. So economic, social and environmental information should be added on the spatial-temporal information model.

Urban planning needs to access and consume a large amount of data. Planning related information consist of 2D map, 3D urban model, thematic information, historical data, national statistics, local survey, and various policy and regulations etc. Planners need to access data sources individually and then combine the results manually every time. This is a very tedious and time-consuming task. The cost of gathering and processing this data is arguably the most significant cost for planning analysis. Effective decision support depends on the integrity and reliability of the information and knowledge available to decision-makers. Therefore, an integrated nD information model is needed in the support of urban planning.

2.2 The Concept of nD Urban Information Models

The concept of nD urban information model was presented in (Wang 2004b; Tanyer 2005). Fig.2 shows the concept of the urban nD information model. The urban information model should integrate the multi-dimensional urban aspects like economy, society and environment with 3D urban model plus temporal dimension. ND urban information model will provide a comprehensive information support to various urban planning application systems.

This nD urban model can integrate diverse and scattered data sources together by integration methodology and implement the interoperation between various datasets. So this nD urban model essentially is an information framework or infrastructure for data integration and interoperability. This framework will employ the emerging data management technologies like database, XML, middleware. And it will include the elements like standards, metadata, ontology and data services. It can meet the basic information requirement for urban planning and facilitate data collection, documentation, access, exchange and transfer at urban scale.

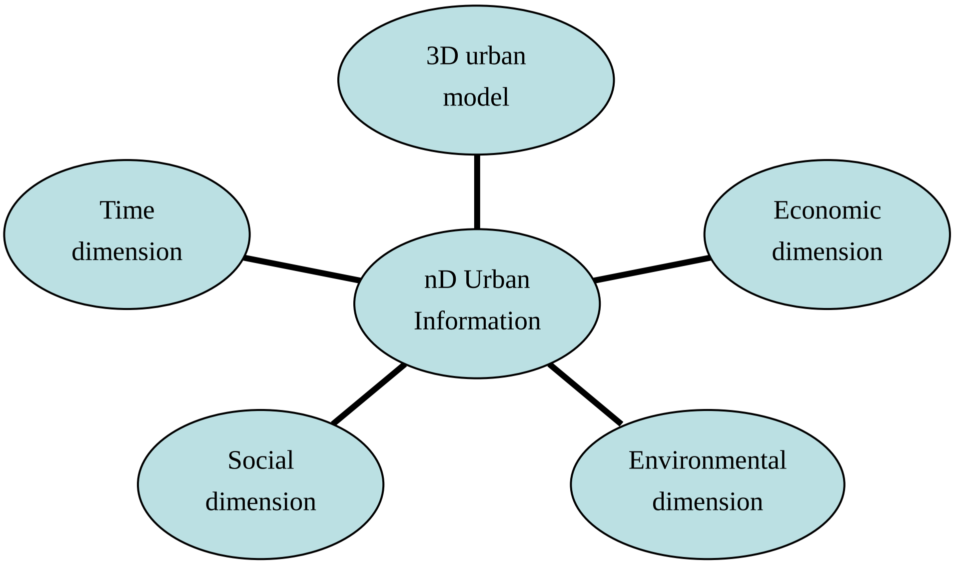

FIG. 2: Concept of nD urban information model

2.3 Urban Datasets

Cities need to be described by a variety of datasets due to the complexity and diversity of the urban environment. These datasets may come from various aspects such as population, crime, business, employment, and transport information etc and use many different data types. And the volume of the data is huge.

There are many different data classification methods. We categorize these datasets into two groups according to the general semantic consideration of the data sources:

- Spatial data
  Spatial data mainly describes the physical structure of urban environment (3D city model). It includes geometrical and topological information like Geospatial Information (GI), Digital Terrain model (DTM), CAD model of buildings etc. Geospatial information is a vital element of the urban information model but lack of 3D detail (limited to 2D or 2.5D representation). Detailed 3D city model require significant effort, time, and cost. 3D laser scanning is very helpful in capture the existing urban detail for computer models. Our research work on using 3D laser scanners to capture the building data can be found in (Arayici 2004). Spatial information are usually organised as a collection of files in a file system or as a collection of tables in a database management system.
- Thematic data
  Thematic data describes different themes like population, crime, housing and transport etc of urban environment. These kinds of data can be census data like the population of a ward or attribute data like the name of the building. Some of thematic data are well-structured data and can be organized into relational database; some of them maybe semi-structured data like XML or HTML document. While the others are just unstructured binary file like text, image, audio, video or other documents.

These datasets may appear to be independent from each other, but in fact they all have some relationship with each other. Intelcities' Work Package 5 vision report presents one such example. Equipment monitoring traffic at the Trafford Shopping Centre is used only to give those responsible for traffic an overview and understanding of the situation at any one time. The information can alter the delay and timings of traffic lights around the Centre and better control the flow. However, this information has value beyond traffic management. It is part of the information view of the economic impact that places like the Trafford Centre have on a region. Traffic analysis can take on a retail / economic context and begin to reveal further the profile of visitors.

Geographical information is the core to the information integration as geographical information providing the structure for collecting, processing, storing and aggregating the data. Research shows 80% of municipal information is geo-referenced (Curwell 2002). Indeed, Geospatial information is often the only factor different datasets have in common. Geographical location is a unique mediator for integrating diverse types of data into a common framework. Geographical location could be in different forms like (x, y) coordinates, postcode, street name, place name etc.

However, this inconsistent geographical information has been a major problem when trying to produce and compare meaningful information over time. For example, there are many different geographic unit types (administrative, health, electoral, postcode etc). Their boundaries frequently don't align and the boundary, area names and codes keep change. This causes a lot of problems with regards the information integration. The following section will discuss those challenges.

2.4 Challenges of nD urban information model

As presented before, nD urban information model is an information integration and data interoperable infrastructure. Data heterogeneity, autonomy and distribution are big challenges for this nD urban model.

2.4.1 Data heterogeneity

Data heterogeneity refers to the incompatibilities that may occur among distinct datasets. Each data source might model the world in its own way. The representation of data of the similar semantics might be quite different in each data source. For example, each might be using different naming conventions to refer to the same real world object. Moreover, they may contain conflicting data. In general, heterogeneity problems can be divided into three levels (Bishr 1998a; Fileto 2001; Visser 2001):

- Syntactic heterogeneity

Syntactic heterogeneity refers to discrepancies in the representation of semantically equivalent information. The distinct data sources may use different data models, different data types and formats.

- Schematic heterogeneity

Just as its name implies, schematic heterogeneity means different data source using different schema. Schema integration generates a mediated schema that characterizes a set of data sources to solve the schema conflict.

- Semantics heterogeneity

Semantics heterogeneity refers to disagreement about the meaning, interpretation or intended use of the same or related data (Sheth 1990). That may include naming conflicts (synonyms, homonyms) and scaling & precision conflicts.

2.4.2 Data autonomy

Most of planning departments have various existing systems and legacy data. In general terms, legacy systems are environment-dependent and self-contained. Planning department need share relevant data from other partners. You cannot force other partners to act in certain ways. As a natural consequence of this, they can also change their data without any announcement to the outside world. Building the planning application will not start from scratch due to the economic and organizational reasons. The advisable integration strategies are leaving the legacy systems and data unchanged. In order to keep the autonomy of the data sources, we argue that data integration should not imply to physically integrate data into a higher level consolidated and standardised data pool.

2.4.3 Data distribution

Distribution refers to the physical distribution of data over multiple sites. Data sources that have to be integrated do not always reside on the same place. It's likely to be that they are on different hardware platforms and operating systems and across different organizations and agencies. Planner may not have administrative control over them, cannot modify their structure, or write data to them. How to communicate between the dispersive data sources is an issue that need to de addressed when creating an integrated system and choosing the appropriate architecture.

3. DEVELOPING nD MODELLING DATABASE – DATA MODELLING APPROACH

Database technology, as a main data management approach has been developed and widely used for many years. Using database technology to implement urban datasets integration and tackle the problem facing nD information model was attempted in Work Package 7(WP7) of the Intelcities project. The aim of WP 7 is to design, build and evaluate components of an interactive virtual urban planning environment as part of the e-City platform. ND modelling database is the base of this interactive virtual urban planning environment.

3.1 About Data modelling

A data model is in essence a representation of the data and their relationship and provides a conceptual or implementation view of the data. This conceptual model would include entities, the relationships between entities and the rules to manage operations on the objects. A data model provides system developers and users with a common understanding and reference point (Longley 2001). The process of data modelling includes: Identifying and describing the information requirements for an information system; Specifying the data to be maintained by the data management; Specifying the data structures to be used for data storage that best support the information requirements.

Data models play an important role in today's GIS software applications as the types of users' tasks are affected from how real world is modelled in a computer environment (Longley 2001). For developers a data model is the means to represent an application domain in terms that may be translated into a design and implementation of a system. For users, it provides a description of the structure of the system, independent of specific items of data or details of the particular application (Worboys 1995).

3.2 Conceptual urban data model

In Work Package 7 of the Intelcities project, an nD modelling database has been set up to integrate various data sources. The dataset types were selected with regard to the scenarios envisioned within the framework of Work Package 7, and in relation with five illustrative use cases. These are geographical data model, building features model, pollution data model, life cycle assessment model, as well as crime analysis. The conceptual urban data model is shown as Fig. 3.

The core of the conceptual data model is the abstract entity of 'administrative boundary'. An 'administrative boundary' is defined as the limits of responsibility area. A 'country' could be the largest administrative area. Countries are composed of counties, cities, districts, parcels. A parcel can also be divided into smaller units called 'partition parcels'. The attributes of the administrative boundary are all inherited to these sub classes. The 'administrative boundary' classes such as countries, counties, cities, districts, parcels have relations with geographical entities such as roads, railways, water elements, heritage elements, etc. A parcel may have a building on it. Industry Foundation Classes (IFC) was used to model the building related data. An administrative boundary may also have crime or pollution related to it. A city, a parcel or a user defined boundary unit may be selected for the air, noise pollution and LCA simulations.

Based to this conceptual model, an nD modelling database has been set up. This provides a good solution to WP7's requirements of analytical models and environmental simulations. It is a good example of testing out the innovative nD modelling concept for urban planning. However, no solution is perfect and can solve all the problems. Urban planning could cover many themes like land use, transport, housing, environmental etc, their user requirements can be different. Defining an unified data model that covers every aspects of city environments is a very difficult task and real challenge. Further more, data modelling method will face the issues like legacy data and data maintenance across organization boundaries etc. These issues are discussed in the next section.

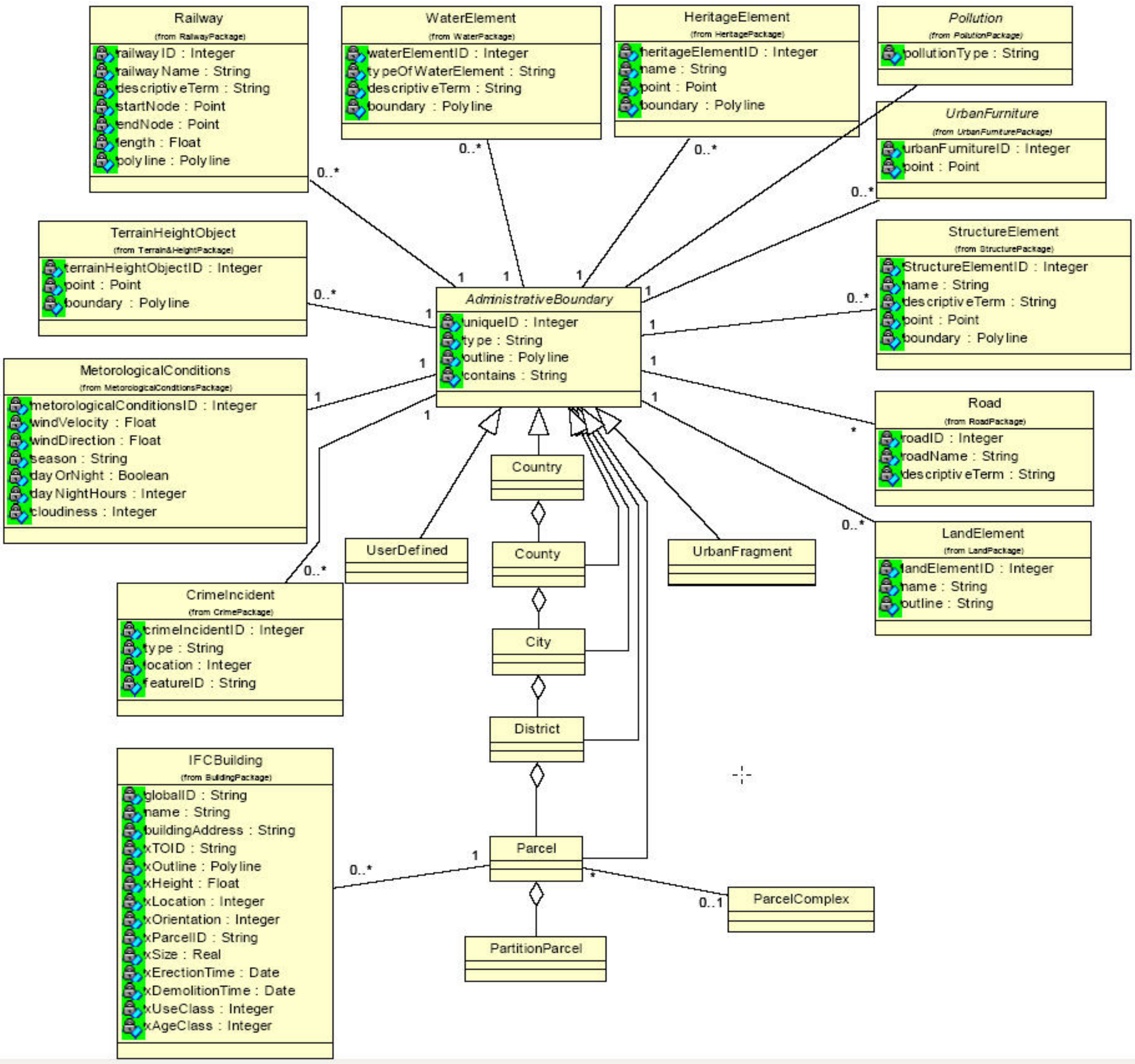

FIG. 3: Conceptual urban data model (Tanyer 2005)

4. DATA INTEROPERABILITY AND INTEGRATION STRATEGIES

As presented before, nD urban information model is an information integration and interoperable framework. Interoperability, i.e. the ability of two or more systems to interact with one another and exchange data according to a prescribed method. Interoperability exist in three levels: application, information, and platform levels (Bishr 1998a). In this context, platform level interoperability focuses on the physical exchange of information between heterogeneous computer systems by using wire or wireless connection. We will not discuss platform level's interoperability since it is beyond the research scope of this paper. Information level interoperability will address issues like standardization, metadata, ontology, data integration technologies etc. Considering application level interoperability, middleware will be discussed.

4.1. Data standardization

Data standardization tries to promote data integration and interoperability across a wider variety of platforms and systems. There are a lot of data standards available from international or national standards to industrial or de facto standards. The problem is how we choose and apply them within the urban planning domain.

One of the most important standards employed in INTELCITIES is e-Government Interoperability Framework (e-GIF). The e-GIF is an initiative of UK government, which is in the process of being officially adopted by the EU, that aims to define the essential requirements for a web-enabled government. It defines the technical policies and specifications governing information flows across government and the public sector. The e-GIF is the basis for web based information systems that already offer significant benefits to citizens in the form of access to city information and interactivity in the form of applications for city services. The e-GIF provides for much needed integration at the interface and information interchange level, via XML and other standards.

Although e-GIF covers a large technology and practice range, decision-making and evaluation process of urban development and planning expect more innovative components. For example, building is an important urban object, describing buildings within the city need to employ the standards from construction industry. Intelcities partners are working hard to incorporate the most appropriate standards. Several of the most relevant data standards are discussed below.

- GML from OGC
  Geographical Mark-up Language (GML) is a XML-based schema for the modelling, transport, and storage of geospatial information. It was developed as a data exchange standards interface by Open GeoSpatial Consortium, Inc. (OGC) to achieve data interoperability and reduce costly geographic data conversions between different systems. The main GIS vendors are now trying to provide GML compliant GIS applications. This approach would overcome some of the problems of sharing environmental data.
- IFC from IAI
  Industry Foundation Classes (IFC) a universal model to be a basis for collaborative work in the building industry and consequently to improve communication, productivity, delivery time, cost, and quality throughout the design, construction, operation and maintenance life cycle of buildings. IFC is a comprehensive data representation of the building model and it is also a set of rules and protocols of how you define the data describing the building. IFC provides a neutral data exchange mechanism for the construction related data. IFC specify the ‘things’ that are used in building construction in an agreed manner and they define a common language for construction. IFC are developed by the International Alliance for Interoperability (IAI) to provide a foundation for the exchange and sharing of information directly between software applications and define a shared building project model (IAI 2002).
- IFG from IAI
  Industry Foundation classes for GIS (IFG) is an ongoing project which is trying to provide a demonstration of the concept of using the Industry Foundation Classes (IFC) model as the specification for the exchange of limited but meaningful information between GIS and AEC CAD systems and vice versa. The aim is to use entities that are already established within the Coordination and Code Checking views of IFC 2x so as to be able to reuse as far as possible the tools, techniques and capabilities already developed by vendors at the AEC side of the demonstration.

Standards are clearly fundamental to the sharing of data across international boundaries. However, data standardization is not the whole solution. Many legacy dataset are not consistent to data standards. Converting existing data into the selected standard format may be difficult if no converting tool is available (Garton et al. 2001). And standards sometimes are not detailed enough to address all of the functions and capabilities that the users of software applications demand(Ceruti 2003).

4.2. Metadata

Metadata is structured data about data that supports the discovery, use, authentication, and administration of information objects” (Greenberg 2001). The meaning of metadata is developing with the emergence of new technologies. Initially in the database community, metadata was called the data dictionary or the catalogue that describes the data (Date 1999). With the development of data warehouse, data mining, Web-based document and multimedia, the content of metadata started expanding. Metadata should not only include the information about the data but also include information on access methods, integrity and security constraints, schema and mapping.

There are three main types of metadata (NISO 2004):

- Descriptive metadata describes a resource for purposes such as discovery and identification.
- Structural metadata indicates how compound objects are put together.
- Administrative metadata provides information to help manage a resource.

Metadata itself essentially is a kind of structured data. Metadata can be either integrated with the document it describes or be part of a separate file.

Describing a resource with metadata makes it to be easily understood. Creating metadata can also facilitate interoperability and legacy resource integration. Metadata guides the schema transformation and integration process in handling heterogeneous data. Metadata is also needed for migrating legacy databases, implement data mining, support decision making and visualization. In short, metadata is central component that is common to all technologies (Thurrasingham 2000).

One of the most popular metadata standards is Dublin Core (http://dublincore.org/). Dublin Core is intended to be simple to use, and general enough to be applied to resources in any discipline. The Dublin Core defines the categories of information to record about a resource (such as a Web page, a document, or an image) in order for the resource to be easily 'discovered'. It has been approved as an ANSI standard (Z39.85-2001), an ISO standard (15836), and has been adopted within the Canadian, Australian, and UK governments among others.

4.3 Data Integration techniques

A number of proven and well–established methods exist that allow heterogeneous data sources to integrate, including gateway, federated databases, data warehousing and mediators/wrapper system{Stoimenov, 2002 #17;Fileto, 2001 #375}.

- Gateway
  A Gateway is some middleware that allows an application running in one DBMS to access data maintained by another DBMS. Most well known gateways are ODBC (Open DataBase Connectivity) and JDBC (Java DataBase Connectivity). Usually, gateways are available only for DBMS that employ the same data modelling paradigm and do not provide location or interface transparency. Hence, gateways are not versatile and do not offer support to establish a homogeneous view of heterogeneous data.
- Data warehouse
  The data warehousing approach, as described by Voisard and Juergens (Voisard 1999), implies accumulation of data in a few well-defined and tightly connected data stores, where information integration is “pre-computed”. In order to integrate data from multiple sources, this approach extracted the data from these sources, transforms into a common schema, and loaded into a single, unified database for the enterprise. While efficient for a relatively small number of datasets, this approach is not readily extensible to a larger number of datasets with semi-structured and ad hoc data. For data sources that change frequently, the cost of shipping incremental updates to the warehouse and inserting it correctly is high. The major cost of this approach is in keeping the warehouse up-to-date (Wiederhold 2002).
- Federated database
  A federated database system(FDBS) is a collection of cooperating but autonomous component database systems (DBSs) (Sheth 1990). The component DBSs are integrated to various degrees. Federated database shared a schema and enabled distributed search. In the case of Database Federation, information needed to answer a query is gathered directly from the data sources in response to the posted query. Hence, the results are up-to date with respect to the contents of the data sources at the time the query is posted. Integration of data was achieved through interoperation at the level of communication technology. The result mirrored the sources exactly, and semantic relationship or mismatches had to be handled by the applications.
- Mediator/Wrapper system
  Mediator–based systems are constructed from a large number of relatively autonomous sources of data and services, communicating with each other over a “on–demand” information integration(Wiederhold 1994). Wrappers encapsulate details of each data source, allowing data access using a common data model. Mediators offer an integrated view of the data supplied by a collection of sources and through wrappers. A mediator transforms requests posed according to the integrated view into requests to the data sources, integrating the results. Structural and syntactic heterogeneity may be solved by mediation.

4.4 Application interoperability

Application interoperability refers to system structures that enable, permit, encourage, monitor and direct diverse application environments to work together. Independently designed applications are made to work together by related technology like middleware and components technology. Some of the most popular distributed object paradigms are Distributed Component Object Model (DCOM), Common Object Request Broker Architecture (CORBA), Enterprise Java Beans (EJB) and Web service.

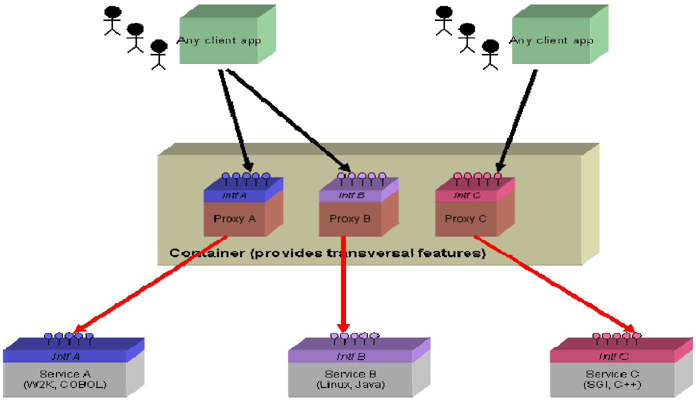

FIG. 4: Proxy container: the whole picture (Source: WP6, Intelcities)

Intelcities' e-City platform will provide "inter-operable" services to citizens and businesses in the domain of e-Governance. WP6 of Intelcities project presented the "proxy container" approach for application interoperability as shown in Fig. 4. The solution relies on well-known concepts that are already implemented in OMG's CORBA component model.

Web service is now the hottest topic in this area. The core components of Web service include:

- Simple Object Access Protocol (SOAP): A lightweight protocol for data exchange in a distributed environment.
- Web Service Description Language (WSDL): used to describe the operations provided by the service.
- Universal Description, Discovery and Integration (UDDI): used for service registry.

UK government's e-GIF recommends that future Web based services are to be based on SOAP, UDDI and WSDL.

These multiple issues and supporting technologies are being used in different applications to integrate multiple autonomous, distributed and heterogeneous data sources across the whole world. This confirms that no general solution exists. Currently, mediator/wrapper structure and Web service method are the favourite choices. It is noted that the choice of integration and interoperation methods must be matched to application requirement. A hybrid approach is needed that can combine several methods and is based on the related data and metadata standards, ontology etc.

5. CONCLUSION

It is always a challenge to consider city issues holistically in city planning processes. The rapid development of information technology has great potential to address such a challenge. By using IT, data can be collected relevant to different city issues and integrated together for later use in city planning. In this paper we have shown how data sets can be integrated at different scales by developing an nD urban database at the urban scale. The integration and interoperability strategies of urban data sets have been discussed particularly with reference to use in urban planning decision-making.

The further research work for nD urban information model will include the following several issues. The first issue is information requirements analysis: building a detail urban nD model data model must be based on the user requirements, this includes: identify organizational structure; determine the data that supports functions, organize data into groups. Only after these can we define and describe the set of objects of interest, and specify the relationship between them. The second is temporal dimension of nD model. Planning information can come from the past and the present. Temporal dimension is necessary to be included in ND information model. Temporal data management is still a tricky problem and a lot of work need to done. Other issues like ontology &semantic integration, knowledge and work flow management should also be addressed in the future.

Rather than supplying comprehensive solutions this paper illustrates the work needed to be tackled in this area. As these issues are better understood, we should be able to build interoperable database that can seamlessly integrate various urban datasets and support computer and human decision making to enhance the management of cities.

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