Framework for Malaysian 3D SDI in CityGML

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Key words: External code lists, CityServer3D, Malaysian 3D SDI, 3D City Model interoperability

SUMMARY

The term Spatial Data Infrastructure is normally used to describe metadata relevant to the collection of technologies, technical methods and processes, policies and institutional arrangements that facilitate the access to 3D spatial data. This paper describes a framework for 3D geospatial data infrastructure based on OGC (Open Geospatial consortium) Standards in Malaysia. The external code lists based on local culture, vegetation and heritage landmarks were proposed and approved for indexing 3D city objects of Malaysia. These code lists can be used between different governmental agencies as a communication tool and utilized for indexing in the 3D spatial database. There are some predefined code lists from other countries such as Germany, which can be utilized for Malaysian context as well. These code lists can be defined for all the street furniture and façade textures in applications e.g city planning, built environment, disaster management etc. The code lists can also be used for the objects on the façade in different layers such as windows, doors and backgrounds to enhance the usage of 3D SDI for a variety of privileges from end-users to professionals in the near future. The framework for web-based application for connecting to CityServer3D was introduced. CityGML as a standard data model can be utilized for developing Malaysian 3D SDI. In this research deferent methods were applied for converting 3D models to CityGML format. Implicit geometry representation for visualizing uniform shapes such as coconut or palm trees and other street furniture was addressed.

1. INTRODUCTION

The framework attempts to utilize the available OGC Web services such as Web3D Service. Features that have been implemented by (Basanow, Neis, Neubauer, Schilling, & Zipf, 2008) seem very appropriate with some modification to suite local requirements in Malaysia such as variety of vegetation and roof types. These can be utilized within CSW (Catalogue Service Web), WMS (Web Map Service), WFS (Web Feature Service), WCS (Web Coverage Service), WPS (Web Processing Service), OpenSL (Open Sound Library), OpenGL (Open Graphics Library), etc. Semantic modeling and Surveying technology like total stations, terrestrial or airborne laser scanners or photo matching techniques from stereo photogrammetry or pictometry techniques might be employed for the 3D virtual geometry reconstruction to a certain extent based on client request along with real or procedural textures. However, only the visible surfaces are registered. This means that neither hidden parts nor the meaning of the surfaces or their belonging to specific object types can be extracted from these techniques. The same situation applies for the multitude of 3D models that are created within CAD (Computer Aided Design) and computer graphics systems like

SketchUp or Autodesk's 3D Studio Max. These models generally consist of geometry and appearance information, but do not represent thematic information and the meaning of the objects. Thus, they also cannot be used for BIM (Building Information Model) applications. (Nagel, Stadler, & Kolbe, 2009) discusses several aspects of CityGML (City Geography Markup Language) including the characteristics of the language. CityGML is a standardized information and data model which puts focus not only on the objects' geometry but also on their semantics, topology, and appearance. Key features of CityGML are:

- Objects may comprise coexisting geometric representations for different Levels Of Detail (LOD concept).
- Topological relations between objects can be recognized via links be-tween geometries (XLink concept).
- Complexity of the variable in the geometry, semantic and coherent structures (Stadler & Kolbe, 2007).
- Aggregation hierarchies on the part of both geometry and semantics support complex object structures (hierarchical structuring).

BIMs can be used as a detailed semantic modeling the same as CityGML and external code lists. It might be employed for enabling interoperability between varieties of applications in the near future. BIM-based Integrated Project Delivery might be a common process for managing a project via distributed systems. Urban management tasks such as disaster management, delivery of goods and services, and cityscape visualization are managed by using GIS and modeling tools. Some of these tasks such as response time for fire management, require detailed geometric and semantic information about buildings in the form of geospatial information, while tasks such as visualization of the 3D virtual city require less (geometric and semantic) information. Nowadays service-oriented architectures are becoming more popular in terms of enabling integration and collaboration over distributed environments. An enhancement for a BIM Web Service pattern proposed by (Isikdag, Underwood, Kuruoglu, & Rahman, 2011) called RESTful BIM that will help interoperability. There are some ongoing research for higher interoperability and transfer of semantic data between BIM and CityGML which is not completed due to following reasons:

- Weakness of CAD models to store semantic information and spatial relation-ships.
- Although BIMs contain geometric and semantic information about the building elements in an object oriented data structure, the geospatial information models handled and treated the data in a different manner than BIMs, and were insufficient in representing all the aspects of the building Information Models (Isikdag, Underwood, Kuruoglu, & Rahman, 2011).

Nowadays due to availability of broadband and high speed internet, emergence of service-based architectures is feasible for remote applications to interoperate using standard web interfaces. Services can be based on thin-servers along with thicker client side web-based application or thick-servers interoperating with thin client side application as a service. Furthermore because of unlimited number of clients, distributed systems, parallel processing and multithreading can be employed for higher efficiency and better response time. The service-orientated system enables loose coupling of applications over the web. Several applications can communicate and interact with each other without having the detailed knowledge of each other's working environment. Each of these applications or data layers that take part in such a web-based interaction in a serving form as a data or component or application service is known as a web service. Service Oriented Architectures (SOA) is software architecture built upon web services. The pattern RESTful BIM is designed for facilitating service-oriented and model based interoperability in the Architecture, Engineering, and Construction (AEC) industry. RESTful BIM pattern concentrates on interoperability via fine-grained web interface in a service-oriented nature. The differences between 3D SDI and BIM, forces the developers to simplify the geometry and semantic information while converting from BIM to 3D SDI. This means that BIM supports more detailed and accurate data than 3D SDI because of the type of application. The concept of integration of RESTfull BIM and geospatial information is illustrated in Fig.1. The database is on top of the Relational Data Base Management System (RDBMS), similar to Geospatial databases along with topology and location information.

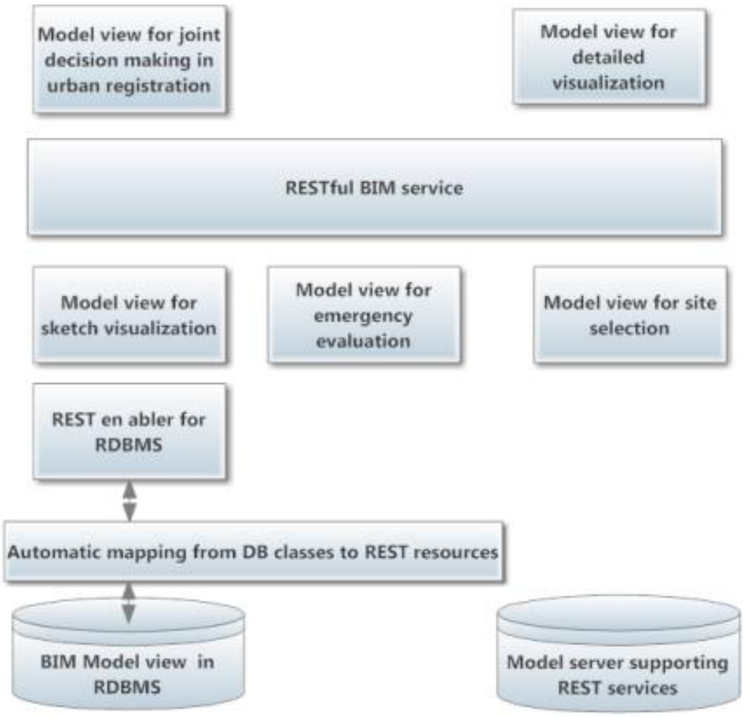

Fig 1. (Isikdag, et al., 2011) The Geospatial views for the RESTful BIM pattern.

2. CITYGML

2.1 Servers and Clients of CityServer3D

The server stores data in the database, accessible via variety of interfaces. The CityServer3D uses a meta-model to handle the queries. After processing the query, the result can be transferred in various ways to other server's functional unit or clients via different interfaces in 2D or 3D formats. The interoperability of the server must be guaranteed for data exchange securely and confidently. E-commerce can be used on the system based on the server components for authentication and transactions monitoring and recording. The system consists of different layers such as Interface Layer (IL), Converter Layer (CL), Functional Layer (FL), Data Schema Layer (DSL) and Data Base Management System Layer (DBMSL). The DBMSL is based on relational concept and Oracle Spatial and DSL composed of GeoDB1, GeoBase2, which can be employed not only for geometry but also for storing thematic and spatial classification of the data sets. The Controller Unit (CU) controls the interaction between layers (See Fig. 2). Convertor Layer deals with different formats such as

DGM (Digital Geospatial Metadata), VRML (Virtual Reality Markup Language), SVG (Scalable Vector Graphics), shape files, CityGML and etc. Two tools are integrated for the clients of CityServer3D to manage the contents and access the 3D city model. Firstly, a web based visualization system and secondly, management of the database for importing and exporting data is necessary for the clients system (Haist & Coors, 2005).

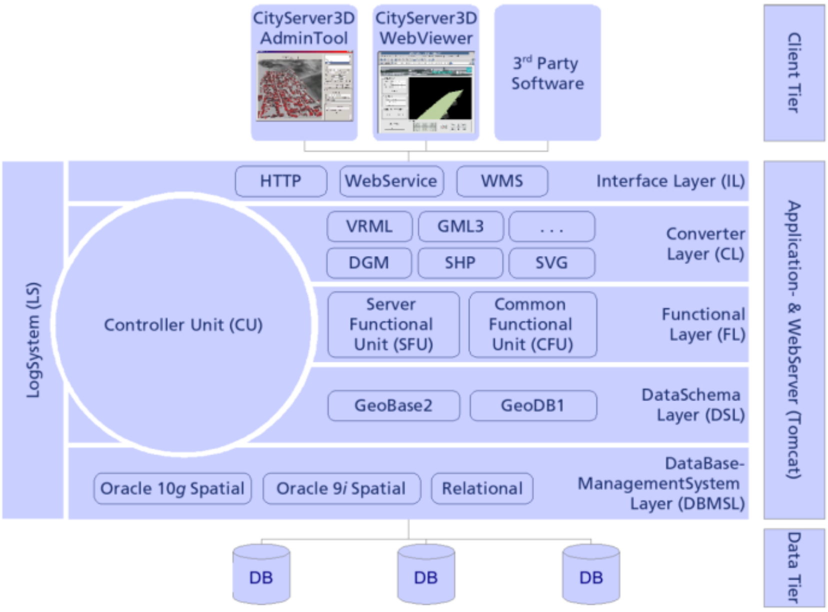

Fig 2. (Haist & Coors, 2005) Architecture of the CityServer3D

2.2 Malaysian 3D spatial data infrastructure

For To achieve the integration of those spatial data, applications and services, a 3D geospatial data infrastructure has to be built in order to connect the existing information “islands”. The core component of this data infrastructure is a domain specific ontology that specifies the knowledge stored in the overall city information model. CityGML is a candidate for such ontology (Groger, Kolbe, & Czerwinski, 2009). It was accepted as an OGC standard for the representation, storage and exchange of virtual 3D city and landscape models. CityGML is based on a rich, general purpose information model in addition to geometry and appearance information. For specific domain areas, CityGML also provides an extension mechanism to enrich the data with identifiable features under preservation of semantic interoperability. This extension mechanism is essential to make use of CityGML in various other applications such as flood simulation and energy management. From BIM, the industrial foundation classes (IFC) developed by the International Alliance for Interoperability (IAI 2007) is a well-defined data model for data interchange of building information models. The definition of a mapping of both CityGML and IFC is a future challenge that would result into a city information model at all levels from city-wide models to high detailed building information model. The second challenge towards a 3D geospatial data infrastructure is the definition of standard interfaces to access distributed data sources. These interfaces will enable individual access to the relevant information sources for a specific task. The OGC working group 3D Information Management (3DIM) is developing such interfaces to support a framework of data

interoperability for the lifecycle of building and infrastructure investment: planning, design, construction, operation, and decommissioning. Web service specifications for visualizing 3D city and landscape models are needed (Schilling & Kolbe, 2010). The Malaysian 3D SDI aims to provide 3D information to many users within the existing Malaysian Geospatial Data Infrastructure (MyGDI) framework. This MyGDI, basically contains various 2D spatial data and layers. The current research project with the Malaysian Centre for Geospatial Data Infrastructure (MaCGDI) could be part of "bigger picture" of the proposed 3D SDI or the SDI roadmap to serve the community with appropriate interface especially applications like navigation, urban planning, police simulation and crime monitoring system, building management, homeland security.
For instance, in Putrajaya 3D project the semantic information were defined along with external code lists and Malaysian 3D SDI within CityServer3D. Information such as, name, roof type, number of the floors under the ground level, number of the floors above the ground level and etc. CityServer3D has a very nice graphic user interface for adding data and attributes similar to DDL (Data Definition Language) and DML (Data Manipulation Language) for end-users. The system automatically updates CityGML file based on defined external code lists. LOD4 also tested for levels 10 and 11 of MaCGDI building including majority of furniture such as computers, desks, chairs and armchairs, tables and structures such as stairs, lifts, toilets and so on almost 19MB of data (See Fig. 3).

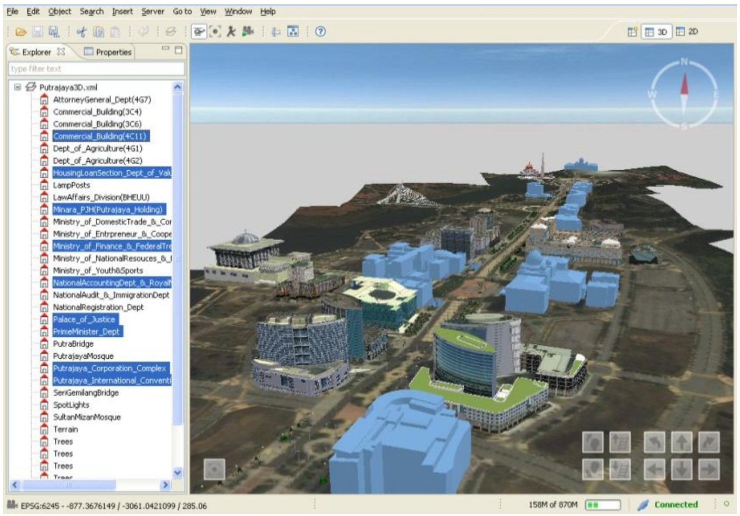

Fig 3. Alizadehashrafi, B. (2012) Semantic modeling of Putrajaya in CityServer3D and CityGML based on 3D SDI.

3. A SUSTAINABLE 3DSDI

3.1 Standardized Web Services

Developing 3D data infrastructures along with general SDIs in particular is an important issue to achieve sustainability. Mostly in temporary limited research projects the collected data gets lost when the project is finished because of the absence of the persons or researchers who know where the data is, how to make use of the data, which formats are available, how to update and maintain and etc. To avoid these kinds of problems the spatial data for Malaysian 3DSDI should be stored in a standardized way and provided by different geographical web services along with documentations and instructions for usage. With the use of the standards of the Open Geospatial Consortium (OGC) it is possible to gain interoperability, which means that the data can not only be used by the web application but also it can be accessed with any GIS system based on OGC standards. This method guarantees flexibility in further usage of the data beyond project duration. For instance the web atlas is fed by four different OGC-Web-Services (OWS) listed as following (Auer, Höfle, Lanig, Schilling, & Zipf, 2011).

- WMS for the 2D map presentation
- WFS for vector data
- WPS for analysis processing
- W3DS for the 3D scenes

This can be implemented for Malaysian 3D SDI as well. W3DS was in the state of an OGC discussion paper to become a new standard (Schilling & Kolbe, 2010). Malaysia 3D SDI started from Putrajaya 3D project based on these initiatives in 3D GIS research Lab in UTM.

3.2 Integration of Data Infrastructure Design

Integration of an existing XML document database and service used and maintained by the historians into the 3D SDI design was a challenging work on the service infrastructure level. This XML database stores the text-scientific results, transcriptions, catalogue of meta-data for the inscriptions, context data about inscription sites and caves and other information. The XML documents about the inscriptions sites, caves and the metadata documents have been supplemented with a spatial component in form of geographic coordinates. This opens up the potential of spatial analysis and visualization of the stored information. As the XML documents do not make use of geographic standard formats it cannot be distributed by OGC Services directly. To enable a standardized access to the data as well as to support the given structure of the XML database, an automated conversion step has been integrated which pulls new documents, whenever they are available, from the XML database and writes them as Simple Features into a spatially enabled PostgreSQL12 database with PostGIS extension (See Fig. 5). From this source the information can be distributed easily by the different OGC services to the web client or any other GIS client. Archiving of new XML data is feasible via XML editors such as notepad++ along with database connection and ensures automated propagation update of the PostGIS database that new features will be automatically shown on the map client and are available for GIS analysis through standardized geo-data interfaces. In this case the OGC-WMS and OGC-WFS interface is provided by the Open Source software GeoServer. The OGC-WPS has been realised with pyWPS using GRASS-GIS processes behind it while the W3DS is an implementation of the University of Heidelberg (Basanow, et al., 2008). The provided data can be received via user-friend graphic user interface (GUI) which can convert the data to XML schema before feeding in the form of XML database.

4. CODE LISTS AND EXTERNAL CODE LISTS

In order to represent the object attributes of the city, having an enumerative range of values is necessary and the concept of dictionaries as provided by GML should be used. The values are defined in a file called CityGML_ExternalCodeLists.xml, which comes with the CityGML schema document, but is not a normative part of this schema, since it might be modified, augmented, replaced by users or other communities. The actual values in the file CityGML_ExternalCodeLists.xml are a suggestion of the SIG 3D (Special Interest Group 3D). In the process of designing semantic and thematic information for 3D city objects, these predefined attributes are necessary to assign to these objects which can be standardized for each area and country such as Malaysia. Attributes are employed to classify the objects and recognize them via queries or clicking and selecting the objects within 3D virtual environment of CityServer3D. It is similar to indexing system and a unique value relates to each attribute within a single file. These values are defined according to the name of attribute. The files are placed in a directory, which is called code lists. It is possible to extract the code list from the CityGML schema file and change or modify according to the user's requirements. These code lists are defined by Open Geospatial Consortium (OGC) in CityGML.

The external code list file defines attribute values and assigns a unique identifier to each value. In a CityGML instance document, an attribute value is denoted by an identifier of a value, not by the value itself. These identifiers are known terms for the operators and users. Thus, printing or typing errors are avoided and it is ensured that the same concept is denoted the same way, by the same identifier and not by two different terms with identical meaning. This is why the use of code lists facilitates semantic interoperability, since they define common terms within an information community. Furthermore, the dictionary concept enables more than one term to be assigned to the same dictionary entry, thus the same concept may be explained in different languages. To differentiate between the languages, code spaces are used. An example for an enumerative attribute is RoofType, which is defined by the external code list file (See the appendix).

'DefinitionCollection' element is used in the dictionary concept for representing the values of an attribute, where each value is given by a Definition entry. In CityGML a definition entry is identified by the name element, which is qualified by the SIG 3D code space. The unqualified name element represents the value of the attribute and an optional description defines the value. CityGML does not use GML identifiers (gml:id) to link to attribute values, since IDs are restricted syntactically, and must be globally unique, which is not feasible for code lists (Groger, et al., 2009).

For instance external code lists of the building model can be summarized in the following types, whose valid values are explicitly enumerated in an external code list.

- BuildingClassType
- BuildingFunctionType
- BuildingUsageType
- RoofTypeType
- BuildingInstallationClassType
- BuildingInstallationFunctionType
- BuildingInstallationUsageType
- IntBuildingInstallationClassType
- IntBuildingInstallationFunctionType
- IntBuildingInstallationUsageType
- BuildingFurnitureClassType
- BuildingFurnitureFunctionType
- BuildingFurnitureUsageType
- RoomClassType
- RoomFunctionType
- RoomUsageType

5. INTEROPERABILITY AND 3D CONVERSION PROCESS

Fig 4 illustrates the conversion process along with 3D model production pipeline from left to right. As it can be seen in column 2 the data can be exported in 3D format from SketchUp in different formats such as WRL, DAE, 3DS, XML and CityGML. 3D model in Collada file format can be utilized via MultiPatch feature class within ArcScene. It is also possible to create the MultiPatch feature class automatically via "Arc tool box -> 3D analyst tools -> conversion -> from file -> import 3D files" in ArcScene software. Unfortunately importing the WRL file format into SketchUp is not possible until now but 3DS. This is why the process of converting the WRL file format to SKP file format can be done through 3DMAX software. In this case the WRL file format can be imported to 3DMAX software and 3DS file format can be exported. The 3DS file format can be imported into SketchUp. By means of using FME or CityGML plugins for SketchUp it is possible to convert any 3D model in SketchUp to CityGML. It is better to make a group for each 3D model in SketchUp and many subgroups within the group before exporting the CityGML file. It can be applied to avoid breaking down the 3D building to its components as many buildings tag within CityGML. The semantic information and code-lists can be added in Fig 4 column 5 via CityServer3D or MySQL database. It is possible to create Web3D-Service Interface via JavaScirpt to visualize CityGML files and use Google spreadsheets for defining, manipulating and updating data. In this case selecting, hovering the mouse on the 3D models, aggregating and many spatial analyses would be possible.

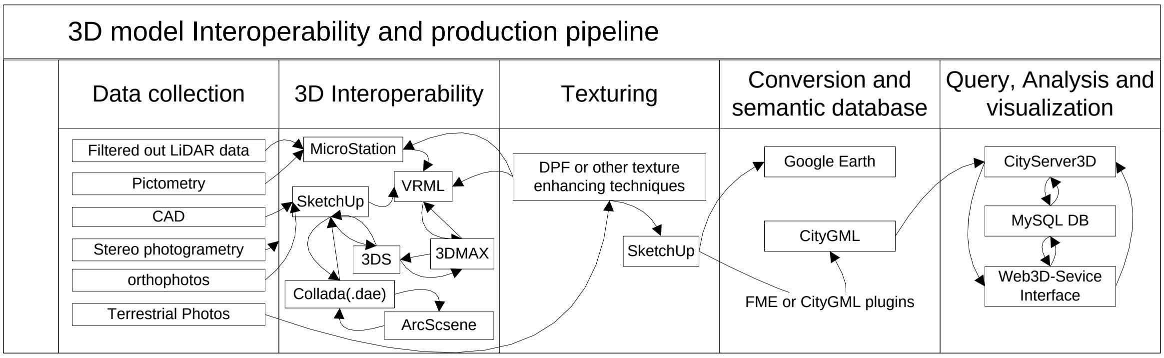

Fig 4. 3D model production pipeline and conversion process.

6. IMPLICIT GEOMETRY IN CITYGML

CityGML supports implicit geometries, prototypic objects, scene graph concepts such as vegetation model, city furniture and generic objects. Implicit geometry is a kind of prototypical geometry which can be generated once and reused unlimited number of times based on 7 well known parameters (3 for rotation, 3 for translation and 1 scale factor). The implicit geometry can be an external file in different formats such as VRML, DXF or 3D Studio MAX on a local or remote machine and loaded to CityGML scene via URL. Alternatively, it can be defined by a GML3 geometry object (Gröger et al., 2008). This concept can be utilized to represent uniform shapes such as coconut or palm trees, street furniture and etc. It can solve the lagging and rendering problems while visualization.

7. PROPOSED EXTERNAL CODE LISTS FOR PUTRAJAYA AREA

External code lists define most of the city objects separately. The code list is mainly used for

the semantic and syntactic interoperability to define the objects in information field.
All the required code lists are not available in CityGML external code lists though it covers most of the city objects. Some code lists are proposed according to the suitability for Malaysia especially in vegetation types such as species type because the vegetation type of each country is different according to the weather and environment of the country.
Some examples of external code lists proposed for Malaysia for different city objects. In Table 1, the code list derived from German Authorities standards ALKIS/ATKIS. The rows in brown color of highlighted code lists are proposed code list for Malaysia in roof types.

Table 1: Code list for Roof Type

RoofTypeType			
Code list for Roof Type			
1000	Flat roof	1070	pavilion roof
1010	monopitch roof	1080	cone roof
1020	skip pent roof	1090	copulan roof
1030	gabled roof	1100	shed roof
1040	hipped roof	1110	arch roof
1050	half-hipped roof	1120	pyramidal broach roof
1060	mansard roof	1130	combination of roof forms
1131	hip and gabled roof	1151	Pyramidical roof
1141	dome roof	1161	Double eaved roof

In addition to the proposed code lists for the roof types of the buildings some code lists were proposed for trees and plant species in Malaysia and Putrajaya main boulevard (Munankarmi, 2011).

8. CONCLUSIONS

In this paper, the definition of SDI and 3DSDI are clarified and some reasons are given for using these metadata as standard methods between governmental sections for better interoperability. CityGML and Malaysian 3D Spatial Data Infrastructure (M3DSDI) along with semantic definition of the objects within a 3D virtual city were discussed in detailed via BIM or geospatial data. Sustainable 3DSDI was addressed and some methods to prevent data losses in the process of interoperability were highlighted. The process of conversion between different 3D models along with implicit geometry representation within CityGML was clarified. The use of code list was addressed for indexing semantic information. Some code lists were proposed for street furniture and vegetation based on Malaysian culture, environment and weather in Putrajaya as a developed test infrastructure. The idea of 3DMSDI can be further developed and extended for whole urban areas in Malaysia along with 3D virtual visualization, analysis and cadastral data.

9. ACKNOWLEDGEMENTS

We would like to appreciate the support of the Association of Authorized Land Surveyors of Malaysia for perusing this research.

10. APPENDIX

<gml:DefinitionCollection gml:id="id356">
<gml:description>Codelist derived from German authoritative standards ALKIS/ATKIS (www.adv-online.de) by S. Schlueter and U.

```
Gruber</gml:description>
  <gml:name>RoofTypeType</gml:name>
      <gml:definitionMember>
        <gml:Definition gml:id="id357">
          <gml:description></gml:description>
          <gml:name codeSpace="urn:d_nrw_sig3d">1000</gml:name>
          <gml:name>flat roof</gml:name>
        </gml:Definition>
      </gml:definitionMember>
      <gml:definitionMember>
        <gml:Definition gml:id="id358">
          <gml:description></gml:description>
          <gml:name codeSpace="urn:d_nrw_sig3d">1010</gml:name>
          <gml:name>monopitch roof</gml:name>
        </gml:Definition>
      </gml:definitionMember>
 ….
</gml:DefinitionCollection>
```


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