3D SPATIAL INFORMATION INFRASTRUCTURE FOR THE PORT OF ROTTERDAM

S. Zlatanova[a], **J. Beetz**[b], **AJ. Boersma**[c], **A. Mulder**[c], **J. Goos**[d]
[a] GISt, OTB Research Institute for the Built Environment, Delft University of Technology, Delft, The Netherlands s.zlatanova@tudelft.nl
[a] Design Systems, Faculty of Architecture, Eindhoven University of Technology, Postbus 513, 5600 MB Eindhoven, The Netherlands, j.beetz@tue.nl
[c] Port of Rotterdam, Wilhelminakade 909, 3072 AP Rotterdam, {aj.boersma, ak.mulder;@portofrotterdam.com}
[d] Municipality of Rotterdam, Department of Surveying, Marconistraat, Rotterdam, jm.goos@rotterdam.nl

ISPRS WG IV/2

KEY WORDS: Infrastructure, Internet/Web, Database, Visualisation

ABSTRACT: The maintenance of the complex infrastructure and facilities of Port of Rotterdam is based on large amounts of heterogeneous information. Almost all activities of the Port require spatial information about features above- and under- ground. Current information systems are department and data oriented and cannot reflect the new process- & project-oriented needed for information exchange. Moreover most of the systems are able to process only two-dimensional data, while increasing number of 3D design models is becoming available. This complexity of activities and diversity of information challenges the Port authority to look for more advanced 3D solutions. This paper presents research in progress related to developing a 3D SII in support of information and process management within the Port of Rotterdam. The discussions and the research findings within this project are very relevant to the development of corporative information infrastructure for any large institution of a company.

INTRODUCTION

The Port of Rotterdam (www.portofrotterdam.com) is one of largest in the world. Spread on the area of 105 sq. km over a distance of 45 km, the Port has 350 million consumers Since 2013 a new extension of the harbour into the see (called Maasvlakte 2) is becoming operational. The harbour area accommodates a large number of companies such as oil refineries, petrochemical industry and general cargo trans-shipment handlings. The fast cargo train to Germany the Betuweroute (www.betuweroute.nl) as well as the densely populated area around the harbour (the City of Rotterdam) also contribute to the dynamic of the region.

The continuous development and maintenance of the infrastructure, facilities, logistics and other assets of the Port of Rotterdam requires the management of a broad spectrum of heterogeneous information. A large number of public and private stakeholders (e.g. companies, environmental authorities, municipalities, institutions and citizens) are constantly involved in the exchange of critical information. Much of this information concerns infrastructural features that are embedded in a constantly changing environment. These features are spatially distributed above ground (topography, cadastral parcels), underground (cables and pipes, geological and geotechnical data) and in the water (depth of the river bed). Our investigations of processes and data as well discussions with the experts within the Port identified the following requirements:

3D data management: The need for 3D data management is motivated by two developments. On one hand many management processes need more accurate information about the third dimension, on the other hand an increasing number of newly design constructions are delivered as 3D Building Information Models (BIM). For example, the underground infrastructure (cable and pipe networks) is becoming very dense and therefore very good estimates for available free underground space are needed prior issuing permissions for new networks. Newly designed quays are typical examples of constructions delivered as 3D BIM. As substantial part of the data sets in the management processes consist of traditional 2D drawings (having limited records about z component as an attribute), incorporating such 3D models becomes a very challenging task.

An integrated 3D model: In the last years the information management paradigm in the Port of Rotterdam has changed from data-oriented to process-oriented. The process-oriented approach poses higher requirements to the information management: one feature needs to be defined only once in the systems to avoid inconsistent and conflicting information. Currently the information is managed by a large number of applications with their own information model. This leads to large data diversity in three domains: geometric, semantic, topology and resolution/accuracy. Geometric diversity revers to the representation of the data sets, e.g. vector, pixel, voxel, etc. Semantic diversity addresses the definitions of features and the matching or integrations between the data sets. Data based on existing semantically rich data models are often converted to semantically poor models and data formats, which leads to information loss. As the data are managed in different systems the topologically correct data sets (when available) need to be converted in non-topologically data structures, which reflect the consistency of data. Resolution & accuracy of different data sets has a critical impact during integration of data for the purpose of one project or process.

These aspects have been addresses by a nationally funded project 3DSDI for the Port of Rotterdam. This paper elaborates on our ideas for an appropriate 3D Spatial Information Infrastructure (SII). The paper is organised as follows: the next section 2 briefly presents 3D developments in the region, which can be used as basis for the intended 3D SII. Section 3 presents the scope of the intended 3D SII. Section 4 briefly discusses some initial results. Section 5 elaborates on the short coming developments.

3D DEVELOPMENTS IN THE COUNTRY AND THE REGION

The requirements of 3D SII for the Port of Rotterdam are also motivated by the 3D developments in Netherlands and the Municipality of Rotterdam. 3D spatial information was highly stimulated by the so called 3D pilot in the Netherlands. Large companies and small businesses are interested in, have access to or possess 3D spatial information (structured and non-structured) in various scales and resolutions and the need for integrated modelling (above, below and on the surface) is growing (Emgard et al 2008, Stoter et al 2010, Van den Brink 2012a, 2012b, Zlatanova et al 2010).

The 3D pilot was initiated by the Dutch Kadaster, Geonovum (the National Spatial Data Infrastructure executive committee in the Netherlands which develops and manages the geo-standards), the Netherlands Geodetic Commission (NCG) and the Dutch Ministry of Infrastructure and Environment. The pilot has passed two phases. The first phase (January 2010 until June 2011) established a uniform approach for acquiring, maintaining and disseminating 3D geo-information in collaboration between 65 stakeholders. A major result of the pilot was a national 3D standard realised as a CityGML Application Domain Extension (Groger et al 2012). The standard is compliant with and based on the existing 2D national Information Model for Geo-information (called IMGeo), which is the actual large scale topographic map of Netherlands. Further technical details about the ADE are reported in Van den Brink et al (2012a; 2012b). The second phase concentrated on more result-oriented issues and prepared several best practice documents. About 100 organisations participated in the second phase (completed in the autumn of 2012). The best practice documents describe tools and techniques that have been developed for supporting the implementation of the 3D standard. Specific attention was paid on the alignment between CityGML and IFC (see www.3dpilot.nl).

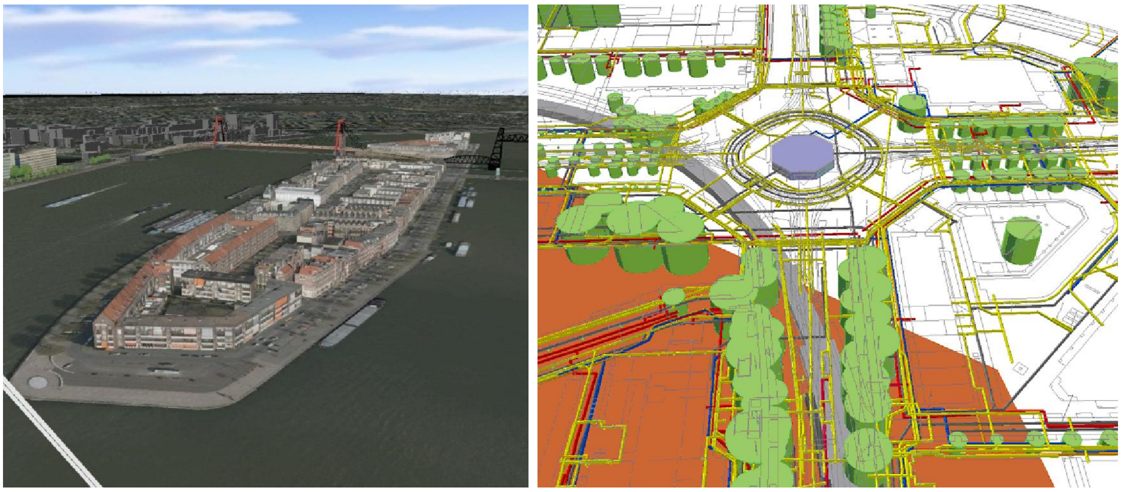


Fig 1: City of Rotterdam: 3D city model (left) and b) 3D underground infrastructure (right)

Another important factor in the discussions for 3D SII is the availability of 3D data in the municipality of Rotterdam. The municipality of Rotterdam is one of the closest partners and frequent contractor of the Port. Most of the data sets needed for the functioning of the Port are obtained from the Municipal offices. A large number of the new quays are also designed by specialised offices of the Municipality of Rotterdam. Since 2007 the city of Rotterdam has a complete height data set and shortly after that starts working on 3D data reconstruction. The municipality was actively involved in the 3D pilot and made available various data sets to the participants in the pilot. The city authority has created and made freely downloadable an object-oriented LOD2, CityGML model for all buildings (http://www.rotterdam.nl/links_rotterdam_3d) (see also Fig.1, left). Additionally, the municipality is responsible for the maintenance of the underground networks in the entire region. It registers all underground networks with their 3D coordinates (Fig. 1, right).

All these developments have established a solid foundation for the development of 3D SII the Port Rotterdam.

3D SII FOR PORT ROTTERDAM

The development of a 3D SII is expected to have a high positive impact for the Port for the internal and external information flow in Port of Rotterdam, as well as for the stakeholders of the entire region. The improved models and system architectures shell increase the productivity and provide additional means to check the up-to-dateness, correctness and consistency of data. An appropriate system architecture that makes relevant information available on the internet will stimulate stakeholders to check and alert for inconsistencies and needed updates (i.e. ‘citizens as sensors’, Goodchild, 2007). A 3D generic model for the Port of Rotterdam is expected to prevent loss of critical data during the construction process (for renovation or new quays at Maasvlakte 2) and to give better overview on the occupancy of industrial territories, infrastructure above and below the surface, keeping records about the geotechnical and geological conditions on land and sea shore. 3D measurements of sand excavations along the shore could be combined with the construction works within areas already in use. The 3D models of the industrial areas can be later used for safety, security and surveillance or visibility analysis (e.g. for security cameras) replacing existing 2D maps.

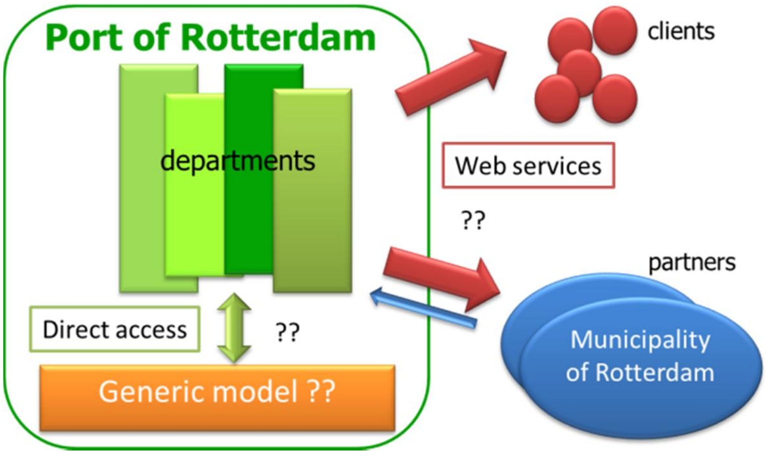


Fig 2: Information exchange for the Port of Rotterdam

Based on initial studies on process and data exchange, communication with clients and companies, and the needed data for management and maintenance of assets, we have identified three different information exchange paradigms between: 1) different departments, 2) Port of Rotterdam and its partners and 3) Port of Rotterdam and its clients (Fig 2.). A generic 3D model (or set of models) has to be envisaged to allow integration of different data sets in one environment and for the different departments, clients and partners. This model should be seen as a major part of the SII and aims at the alignment, harmonization and integration of existing spatial data models as well as the development of additional umbrella meta-models and missing domain models. Related to the model, two aspects require special attention:

- The set of features (assets), which have to be included in the model considering their semantics, geometry, topology, appearance, granularity or levels of detail (LOD). Moving to 3D, it should be also evaluated how to link the concepts of BIM (e.g. IFC) and GIS (e.g. CityGML). The generic model will give the conceptual view on the information to be managed by the Port. Some sections of it will be implemented as data structure, but many sections will be used only as a reference model to obtain data from clients and partners.
- The data structure, which would be most appropriate to maintain the features, which are maintained by the Port of Rotterdam. At present, many data sets are still maintained by individual departments, although large parts of the information are managed centrally in database management system (DBMS). A central management is clearly a choice that will ensure consistency and re-use of information, but will require a data model that can serve the needs of all departments.

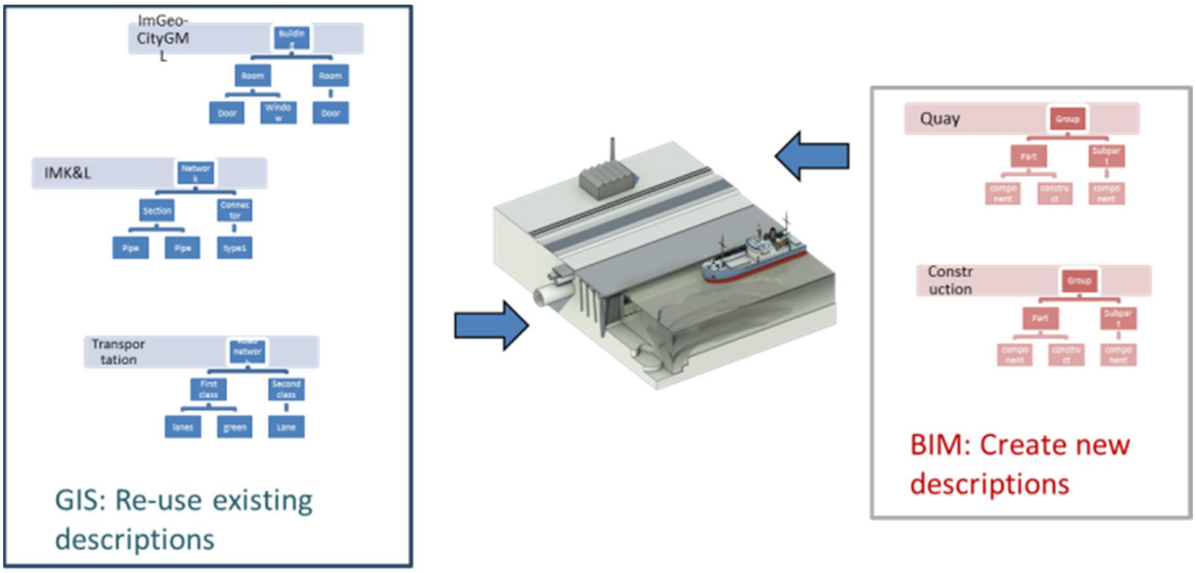


Fig 3: 3D generic model integrating GIS and BIM data: a conceptual view.

The generic 3D model should incorporate data from GIS (existing) and BIM (design) domain (Fig 3). While developing the GIS branch of the model, the following principles will be taken into consideration:

- Features will be defined only once, but all the properties needed for the work of the Port will be maintained. This implies that all the features will be intelligent objects, having strict definitions and consistently structured properties and relationships.

- Features, which can be identified in existing standards (GIS and BIM) will be re-used. A special attention will be given to the Dutch Information Doman Models. Among those models the topographic large-scale model (IMGeo) and the Information model for Cables and Pipes (IMKL) are most interesting. Relevant features from other models will be re-used as well.
- New features will be defined only when similar notations cannot be identified in existing models.
- International standards, discussions and tendencies related to 3D information management will be close followed and taken into consideration. Special attention will be given to developments within OGC and Web3D.

The most important assets within the Port of Rotterdam are the quays. At present, there is no a definition of quays in BIM. Quays are complex constructions and no one has developed a formal description any of the BIM standards. Within this research a new model will be developed for the one of the BIM standards (i.e. IFC).

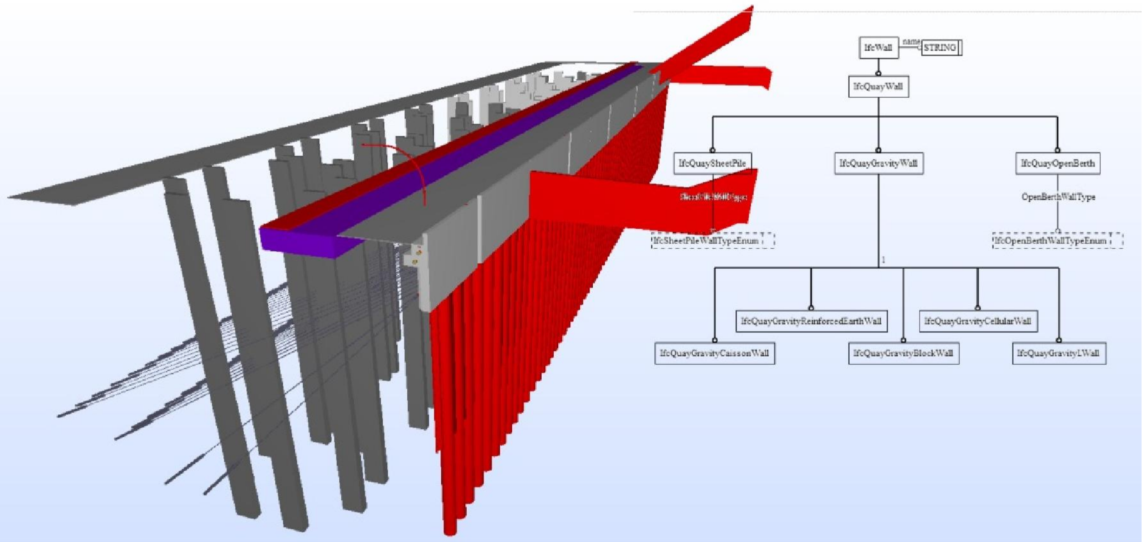


Fig 4: 3D model of quays and top classes of the IFC domain model.

A critical question to be answered is the link between the design and existing spatial objects. As well-know from the literature, BIM and GIS concepts for representing features differ significantly (Döllner, and Hagedorn 2008). A critical analysis has to be therefore performed to evaluate the applicability of the two concepts and estimate the consequences on the generic model. Several options will be investigated: 1) keep BIM representation as core and map to GIS representation whenever necessary, 2) keep GIS representation and convert the new BIM designs upon receive and 3) keep both representation and establish links between semantically similar objects and their elements (Beetz et al 2009; Hess and de Vries, 2006; Hijazi et al 2010). The third approach is being currently investigated since no conversions will be required.

To replace the cumbersome and verbose exchange of file-based information between stakeholders, we intend to develop a Service Oriented Architecture that will allow just-in-time extraction and integration of distributed data sources through web services or direct access. Depending on the type of the users (departments of the Port, Clients or Partners) different levels of access to the generic model has to be provided. In general, the departments have to be able to have full access (read&edit&) to the information from the generic model via the software packages in use. The external stakeholders will be given only read access or a very limited update access. What kind of services will be implemented is still under investigation.

The intention is to reuse existing technologies such as the OGC family of geospatial information access standards through e.g. Web Feature Services (WFS) (Lapierre and Cote 2008), (spatial) queries of partial BIM as provided by BIM Server (Beetz et al 2010) or other BIM related technologies (Coates and Arayici, 2012). On a technological level, mature, open and established technologies like SOAP, Google Protocol Buffers and RESTful services would guarantee their usability in production environments. Which approach will be followed depends on the types of uses and the tasks they need to perform. Related to this is the question of the standards, to be used for exchange of information: GML, CityGML, BIM (IFC) or the Dutch Information Domain Models.

To make efficient use of the structured, interconnected information provided by the model described earlier, data integration and visualization clients are currently in process of development. These allow the selection of relevant spatial data according to the generic model and provide visual means for multi-criteria and multi-dimensional analyses in 2D or 3D to support decision processes. Flexibility and ease of use is provided by their web-based nature, using upcoming vendor-independent, open standards like HTML5 and WebGL.

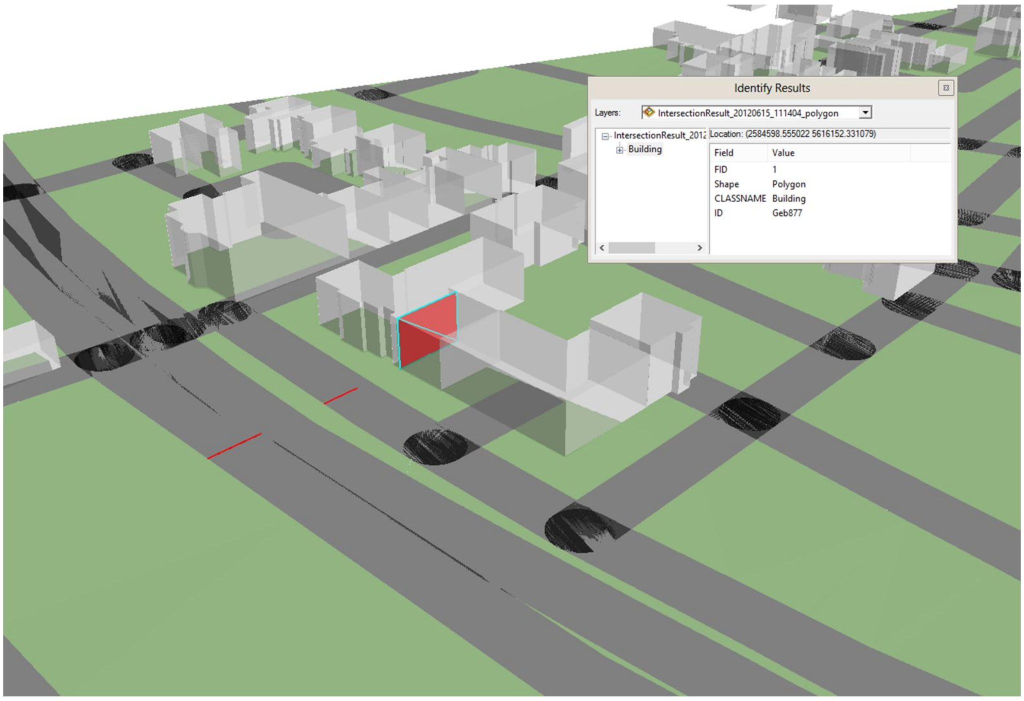
IMPLEMENTATIONS AND TESTS

The developed model and systems architecture will be tested with two scenarios: high-performance quays and underground pipes. Both scenarios have been identified as having critical importance for the Port of Rotterdam.

A quay wall can represent different aspects of information management: an assembly of structural engineering components, a series of logistical units consisting of bollard slots, a piece of real estate or as the target zone of a navigation channel that has been externally contracted for constant excavation to guarantee a certain ship draft for a client. When frequent re-occurring changes, such as renting out a berth to a new client, have to be organised. Presently this is done in an ad hoc process where relevant information is gathered, processed and communicated in an unstructured way involving different internal and external stakeholders. Often objects appear with different definitions by the domain applications. This use case is intended for testing the integrated model (especially BIM and GIS integration) and the performance of 3D spatial analysis.

The second use case is to be used for testing the 3D visualisation aspects of 3DSII. Underground cables and other infrastructural features are obtained from external parties such as the Municipality of Rotterdam in the form of 2D networks (although the data are 3D). The planning, execution and documentation of new infrastructural projects however is depending on additional, three dimensional aspects and needs to be streamlined in order to prevent unwanted side-effects such as cable damage during construction and unnecessary earthworks due to ill coordinated, parallel projects or lack of underground space.

The first developments concentrate on two aspects related to the use of the model: 3D analysis (clip and cross section) and 3D visualisation (using Web GL). One of the largest advantages of a well-structured 3D model is the ability to integrated data in one 3D environment and to perform 3D analysis. Therefore as a first step even before developing the model, we considered important to demonstrate some aspects of 3D analysis and visualisation. A test area was identified and all possible data sets (currently in possession or of importance for Port Rotterdam) were collected and made available for testing the developments.



Layers: IntersectionResult_20120615_111404_polygon

Location: (2584598.555022 5616152.331079)

Field	Value
FID	1
Shape	Polygon
CLASSNAME	Building
ID	Geb877

Fig 5: A profile: all the resulting features are valid objects and inherih the attributes of they belong to (courtesy W. Goedhart)

Our study on the process management revealed that two 3D operations clip and cross section are needed in several stages of the project management of a new development (e.g. quay). Firstly, 3D clip operation is needed within the cost-benefit analysis. The area for development has to be delineated and analysed against all existing assets, which will be affected. This operation is currently performed in 2D, which often leads to miscomputations and inaccuracies. The clips and the cross section must be performed in 3D. The new resulting objects have to be valid and preserve the attributes of the original object. Figure 5 demonstrates the 3D cross section with a vertical plane. Two streets and one building are intersected in with the vertical plane and are highlighted in the figure. The cross section operator can be performed in all directions (and not only vertical). This operation could be a solution to providing 2D geometries to existing systems, which cannot easily be extended to 3D. Presently the developed algorithms can be applied to CityGML models, but the intention is to be adapted for the model that would be developed for the Port of Rotterdam. Presently, the operations are developed considering GIS data types (i.e., point, curve, surface and polyhedron). This means that the more elaborated geometric primitives available in BIM models are not considered. The objects of the quay model are therefore converted to triangular meshes. However not all the objects could have been consistently modified and have been omitted from the test data set.

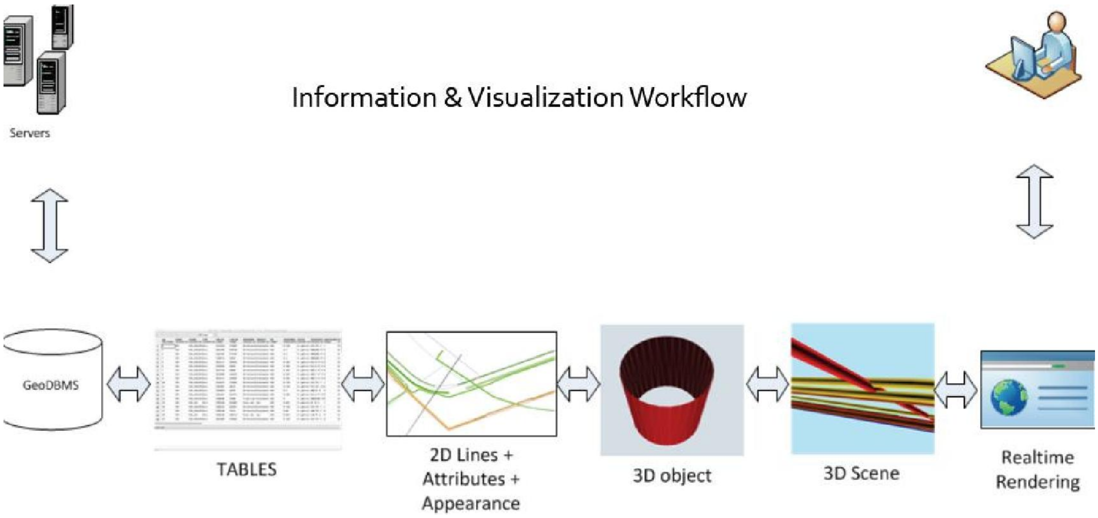


Fig 6: 3D visualisation work flow for pipelines (Guerrero 2012)

The second prototype concerns 3D visualisation. The goal was to investigate and select an appropriate approach for integrated visualisation of above and underground data in one environment. The focus was on pipes and cables. Utility networks are tricky objects for visualisation because they are usually maintained as simple lines and required significant modifications to be adapted for 3D rendering.

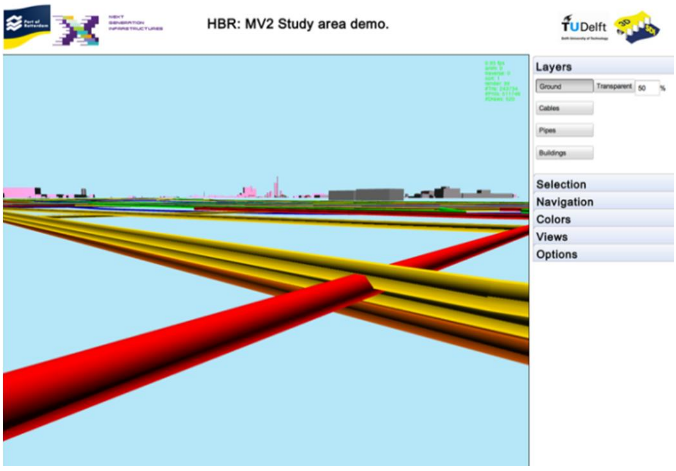


Fig 6: Visualisation of pipes, buildings, surface model (transparent) in WebGL client using X3D/X3DOM (Guerrero, 2012)

Furthermore, the performance of some new technologies such as WebGL (X3D/X3DOM and SceneJS) and Layar was tested. The developed prototype is able to: extract pipes and cables from a data base with their attributes, convert the lines to an appropriate 3D representation, visualise the 3D pipes (using WebGL or Layar) together with above ground information, allow for simple interaction such as query of attributes, switching layers, etc. (Fig 6).

It has been successfully demonstrated that the needed transformations and adaptations can be executed in the required time to make the work with the model comfortable. Figure 4 illustrates the integrated visualisation of buildings (CityGML LOD2), 3D utility networks and surface data (topographic map of 1:10000) (Fig 6). More details on the way 3D pipes have to visualised, e.g. the number of faces, which has to be used to represent one cylinder, the max number of objects that should be visualised in one scene, etc. can be found in Guerrero 2012.

DISCUSSION AND FUTURE DEVELOPMENTS

In this paper we presented the challenges in spatial information management and the intended developments toward corporate 3DSII for the Port of Rotterdam. Our research concentrates on technical aspects of 3D SII, i.e. 3D conceptual model, 3D visualisation and 3D operations to be performed on the model. Several prototypes have been developed, but they are still running independently from each other and from the model. Further developments will address the integration of these components. Although incomplete the prototypes have demonstrated that 3D GIS data (buildings, cables and pipes, and surface model) can be integrated with the quays provided as BIM model. The current approach was to convert the geometries of the BIM model to a GIS data types. However it was not possible to transform all the BIM objects. Large amounts of objects were lost. Current commercial packages still cannot convert BIM models to GIS representations without loss of data. Therefore the current model keeps the geometry as in the original BIM objects.

The most challenging aspect in this research is the conceptual model. As mentioned previously, the model should serve as a virtual container where all kind of (spatial) features can be appropriately accommodated for integrated visualisation and analysis. The model might not be physically implemented in any system, but parts of it can be of use in the different departments or sections of the Port. This also implies that many of the current systems will not need to be modified. The internal models will remain untouched and appropriate mappings (semantic and geometric) will be provided. A formal framework for performing the mappings has to be developed as well.

REFERENCES

Beetz,J., L. van Berlo, L., R. de Laat, and P. van den Helm, (2010) Bimserver.org - an Open Source IFC model server, Proc. of. 27th International Conference on Applications of IT in the AEC Industry CIB-W78, Cairo, November 2010, 1-8)

Beetz, J., J.P. van Leeuwen and B. de Vries, (2009) IfcOWL: A case of transforming EXPRESS schemas into ontologies, Artificial Intelligence for

Engineering Design, Analysis and Manufacturing. 23, 1, 89-101

Coates, P. and Y. Arayici (2012) Optimisation of the BIM authoring tool in Architectural practice: a case study approach, Int. J. on 3D Information Modelling, 1, 2, 30-45

Döner,F., R. Thompson, J. Stoter, Ch. Lemmen, H. Ploeger, P. van Oosterom and S. Zlatanova (2010) 4D cadastres: First analysis of legal, organizational, and technical impact - with a case study on utility networks, Land Use Policy, 27, 1068-108

Döllner,J. and B. Hagedorn (2008) Integrating GIS, CAD and BIM data by service-based virtual 3D city models, Urban and Regional Data Management; UDMS Annual 2007, 157-170 (2008)

Emgård. KL and S. Zlatanova (2008) Design of an integrated 3D information model, Urban and regional data management: UDMS annual 2007, Taylorand Francis Group, London, 143-156

Goodchild, M.F, (2007) Citizens as sensors: the world of volunteered geography, GeoJournal 69, 4, 211-221

Gröger, T. Kolbe and A. Czerwinski, OpenGIS CityGML Implementation Specification. (2012) http://www.opengeospatial.org/standards/citygml (last accessed 25-03-2013)

Guerrero JI, 2012, Three-dimensional reconstruction of underground utilities for real-time visualization, Master thesis TU Delft, 2012, 103 p. avalible at www.gdmc.nl (alast accessed 26.03.2013)

Hess, C. and M. de Vries,(2006) From models to data: A prototype Query Translator for the cadastral domain, Computers, Environment and Urban Systems, 30, 529-542 (2006)

Hijazi, I., M. Ehler and S. Zlatanova (2010) BIM for geo-analysis (BIM4GEOA): set up of 3D information system with open source software and open specifications (OS), International Archives of the Photogrametry, Remote sensing and Spatial Information Sciences, Vol. XXXVIII-4/W15, November 4-5, 2010, Berlin, Germany, 45-49

Isikdag, U. and S. Zlatanova (2009) Towards defining a framework for automatic generation of buildings in CityGML using BIM, 3D geo-information sciences, LNG&C, Springer Verlag, 79-96

Lapierre, A. and P. Cote (2008) Using Open Web Services for urban data management: a testbed resulting from an OGC initiative offering standard CAD/GIS/BIM services, Urban and Regional Data Management; UDMS Annual 2007, Taylor and Francis, London, 381-393 (2008)

Penninga, F. and P.J.M. van Oosterom (2008) A simplicial complex-based DBMS approach to 3D topographic data modelling, in: International Journal of Geographical Information Science, 22, 7, 751-779

Scarponcini, P., S. Camateros, O. Custers, S. Zlatanova and P. van Oosterom, (2008) Introduction to SII, Creating Spatial Information Infrastructures: Towards the Spatial Semantic Web, CRCpress Taylor and Francis group, Boca Raton, xiii-xxiii

Stoter,J.E., J. Beetz, H. Ledoux, M.l Reuvers, R. Klooster, P. Janssen, F. Penniga, S. Zlatanova and L.van Den Brink, 2012, Implementation of a national 3D standard: case of The Netherlands, to be published in: 3D geographical information, Lecture Notes in Geoinformaton and Cartography

Stoter, JE, G. Vosselman, J. Goos, S. Zlatanova, E. , Verbree, R. Klooster, M. Reuvers, 2011, Towards a national 3D spatial data infrastructure: case of the Netherlands. Geoinformation: Organ de Deutschen Gesellschaft für Photogrammetrie und Fernerkundung e.V., 2011(6), 405-420.

Stoter, J., M. Reuvers, G. Vosselman, J. Goos, L. van Berlo, S. Zlatanova, E. Verbree and R. Kloosterg, (2010) Towards a 3D geo-information standard in the Netherlands, International Archives of the Photogrammetry, Remote sensing and Spatial Information Sciences, XXXVIII-4/W15, November 4-5, 2010, Berlin, Germany, 63-67 (2010)

Tegtmeier, W., S. Zlatanova, P. van Oosterom and H. R.G.K. Hack (2009), Information management in civil engineering infrastructural development: with focus on geological and geotechnical information. In: Kolbe, Zhang&Zlatanova (Eds.), Proceedings of the ISPRS workshop, vol. XXXVIII-3-4/C3 Commission III/4, IV/8 and IV/5: Academic track of GeoWeb 2009 conference: Cityscapes International archives of photogrammetry, remote sensing and spatial inform ation sciences (pp. 1-6). Berlin, Germany: ISPRS

Van den Brink, L., J.E. Stoter and S. Zlatanova, 2012a. Establishing a national standard compliant to CityGML, accepted for International Journal of Geographical Information Science IJGIS

Van den Brink, L., J.E. Stoter and S. Zlatanova, 2012b. Modeling an application domain extension of CityGML in UML, ISPRS Archivers, 3D GeoInfo Symposium, Quebec, Canada, 16-17 May. 2012.

Zlatanova, S., L. Itard, M. S. Kibria and M. van Dorst, 2010, A user requirements study of digital 3D models for urban renewal, In: Open House International, Volume 35, 3, pp. 37-46