BIM & GIS CONNECTIVITY PAVES THE WAY FOR REALLY SMART CITIES

Ulf Månsson,
Project Manager, SWECO,
ulf.mansson@sweco.se.

Today, we see several good examples of Smart City and Geodesign initiatives around the world. They often depend on BIM data (Building information modeling/Bygnings Informations Modellering) and spatial data. However, interoperability is a challenge that must be adressed in a more efficient way.
More generally, the question is what is required to take the leap from good examples to broad and mainstream application in urban and regional development?
In this article, some key success factors for this development and described and the important challenges outlined. The V-Con innovation project addressing these challenges is described as a possible solution.

Keywords: Geodesign, BIM (Building information modeling), GIS (Geographical Information Systems), Internet of things, Semantic Web, Smart Cities

CONNECTIVITY

Way back in time, when I started studying GIS and Remote Sensing, I remember discussions like ”Are you vector or are you raster?”. The idea of combining these features would have been considered revolutionary at the time. Also, if you did choose a GIS-tool, you committed yourself to the vendor of the chosen platform and the system´s proprietary file-storage format.

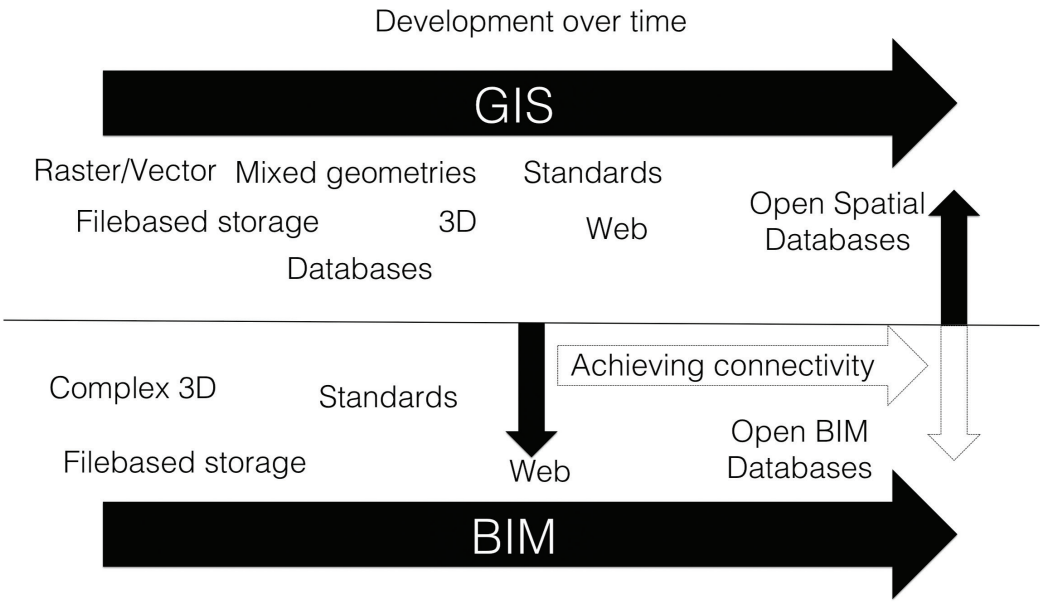

Figure 1. Achieving connectivity between GIS and BIM, Ulf Månsson

Exchanging data between platforms was hard - if even possible at all.

Since the introduction of connectivity to standard databases and the evolving of the Internet - the GIS industry has come a long way. We have standards like GML, WMS and WFS (Reichardt, Mark E. 2012). Interoperability tools are considered a must in most organizations. "We do not want vendor lock in" is a common phrase heard in many organizations.

The official reasons for the fear of "vendor lock in" may vary (Verstraete, C. 2015): It can be an economic motive. If we invest heavily in a platform from vendor A - the cost can skyrocket if the vendor changes the license-model. Also you may be too dependent on a certain expertise. ... It can also be a decision about Open Source or Proprietary. You may feel safer with either side when thinking of the long time aspect.

Personally, I think the most important fact to consider is none of the above. Focus should be on connectivity. Data created, collected and stored by an organization has greater value if it can be connected and combined with other data - coming from any place. *Connectivity* is a cornerstone in two trending fields, Smart Cities and Geodesign.

Smart Cities

There are many different definitions of Smart City but the fundamentals are (Wikipedia 2015):

- Enhancing quality and performance of urban services.
- Reducing costs and resource consumption – thus achieving sustainability.
- More effective engagement with its citizens.

A typical future scenario in a Smart City is often exemplified with emergency response (Enbysk, L. 2013). In a really Smart City, the ambulance personnel not only gets notifications about the fastest route to the correct building, considering all current traffic-related data. They would also get live instructions on which entrance to use and finding a fire safe way to the correct floor as fast as possible.

To achieve the above, all kinds of data must be connected between many different sources and systems leading to useful information and knowledge. With regards to spatial areas, cities have huge spaces and functionality inside buildings. As an example, Dan Campbell at the City of

The Smart City as visualized by August Wiklund, Sweco

Vancouver, explains that just one BIM-model uses ¼ of the space of the 3D GIS-model of the entire city (Safe Software 2015). This means that in many Smart City scenarios, most data will have to come from BIM Systems (Building Information Models) and connect to GIS. Therefore, BIM databases will have to evolve to the same state of openness as GIS (Figure 1) to make this feasible.

Figure 1 explains how GIS and BIM have evolved during time and how different areas have been embraced. Today, the use of Open Spatial Databases can be considered a de facto standard within GIS. However, BIM focus today is very much on WEB-enabling it and not yet on using Open BIM Databases.

Geodesign

Once again, there are many definitions. The following definitions is short and concise enough for this context:

'A design and planning method which tightly couples the creation of design proposals with impact simulations informed by geographic contexts' (Flaxman M. 2010)

Within the geodesign discipline, some of the steps in planning and implementing a new residential area could be:

- Gather information based on existing data such as road-networks, traffic-information, building information, geology etc.
- Perform analysis and simulations. (For example; How will traffic be affected with more residents?).
- Create proposals based on evaluation models and communicate these for feedback among stakeholders and citizens. (Steinitz C. 2012)

In these steps, we need current data, we also create new data and when something eventually is built we should evaluate on the accuracy of the simulations and predictions.

RELATIONSHIP BETWEEN GEODESIGN AND SMART CITIES

One can see that a well-performed Geodesign-process would benefit from existing Smart City information for well-informed decisions. For example, getting information about traffic-statistics and all kinds of sensors and other Big Data sources. On the other hand, one could also see a well-performed Geodesign-process as fundamental to a Smart City. If the designs coming out of the Geodesign process are not stored, updated and kept accessible - they won't help the vision of the Smart Cities.

In regard to data, achieving connectivity in these fields has many barriers, both technical and legal. Fortunately, as more organizations open their datasets, there are now less legal barriers. The technical challenges still remain. Many of these are well known to the GIS industry, and are linked to the difficulties of combining data from different sources.

Examples of challenges:

- Reading and writing from different formats and sources (including open standards and proprietary).
- Combining different types of geometry types.
- Co-ordinate systems and precision.
- How data is layered or have attribute-schemas.

The more complex BIM-platforms have not come as far as the GIS-platforms regarding connectivity. This is quite understandable as these models are so complex with their high level of detail and 3D-capabilities. In reality, most BIM-data live in their proprietary systems, and exchanging information is cumbersome.

THE CHALLENGES AHEAD

The vision of smooth Geodesign processes and blooming Smart Cities will benefit greatly if two specific areas will be addressed.

Accessibility of BIM Data

A lot of effort is being made in standards such as

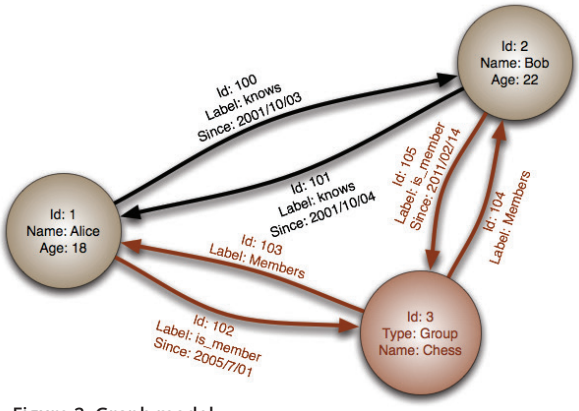

Figure 2. Graph model

IFC (Industry Foundation Classes) to be able to exchange information in an efficient way (buildingSMART 2015). However, it is still very rare that you have storage in open databases where data lives. In the GIS-industry, it can be considered best practice to have a database that owns the information, and different platforms can access this database with modern tools such as version-control, integrity rules etc. Other, non-spatial systems can directly connect to the databases as they use the same technology. This can be exemplified by Microsoft SQL Server and Oracle - databases that are widely used and shared between many types of systems – spatial or not.

The BIM-industry is far from this point. Software tools exist - but they are rarely open for integration (Isaac S et al 2013).

Using BIM-data together with GIS-data in reality mostly means:

- You export a subset of your BIM-model to your GIS database.
- You import a subset of your GIS database into your BIM-model.

You very rarely connect these sources on an object level directly.

Systems understanding systems

When we traditionally think of GIS, it is often in the context of seeing and relating to maps produced for the human eye. That is, the data is presented in a form that allows a human to make a

well-informed decision. This also affects the way data is stored.

BIM is often ”more” intelligent as one of the major purposes is to keep track of details and of how objects are interconnected describing the topology of a building or complex infrastructure-projects. But still - it is humans making most decisions based on what is displayed.

The Smart City concept relies on complex chains of systems communicating with each other. In the ambulance example above, several systems would need to interact. Traffic-information, navigation, BIM with building layouts and elevator systems would need to understand each other.

The traditional way of achieving this is through standard protocols. That is, you ”hard wire” intelligence into systems to understand what other systems mean. A protocol can both describe the physical means of communications and also the standards describing the logic of data. So if two systems understand the same protocol - they can communicate. The drawback is that operating on new types of data demands new protocols. So a Smart City getting smarter by connecting new data would demand a lot of new protocols.

An exciting alternative to using predefined protocols is the ”Linked Data” approach. Linked Data describes a method to communicate data so it can be interlinked and become useful through semantic queries. The approach uses standard Web technologies but instead of serving web pages it can be read and understood automatically by computer systems.

THE SEMANTIC WEB

The semantic web concept is complicated so it will just be touched upon briefly. A cornerstone is the use of Linked Data. *'The Semantic Web is not a separate Web but an extension of the current one, in which information is given well-defined meaning, better enabling computers and people to work in cooperation'* (Tim Berners-Lee, Hendler and Lassila, 2001).

The more traditional way of storing and communicating information is through the relational or object model where you define tables or classes and relate them together according to predefined rule sets or schemas – as most GIS solutions do.

However - a key element for the semantic web is that you store and send information as graphs (Figure 2). You have nodes, edges and properties. Communicating in this triplet-way adds meaning for machines interpreting these connections. As a graph can be dynamic, it can evolve during time and become more or less complicated. This is something that works very well with BIM-models, for instance the IFC-standard that in its complete implementation is very extensive. In most implementations, only subsets of the IFC-standard are used. However, during a projects life cycle, different subsets and parts are being adopted. To support these dynamics in an IFC-model with a relational database is almost impossible but far more possible with a dynamic graph database.

The idea of achieving better connectivity between BIM and GIS systems with help of the above technique is based on the assumptions that:

- It’s easier to model BIM-data as a graph than in a relational model
- BIM-models change over time – something that is possible to handle with new links in the graph.
- Connections between specific BIM and GIS-objects can be maintained with links in the model. (The actual geometries could be stored in the model or it can be links to external storage as physical files. Something called “Hybrid Approach”).

Communicating with a Semantic Web enabled system can be done with special query-languages like SPARQL. These languages provide a way to query graphs over the Web and can be utilized by different systems.

V-CON PAVES THE WAY

The author is currently participating in the PCP-part of the V-Con project (The Virtual Construc-

tion for Roads) that aims to improve the efficiency and effectiveness of the National Road Authorities in Europe. (Read more at http://www.rws.nl/english/highways/v-con)

PCP is an approach for procuring R&D services and consists of a funnel of three phases: challenge solution design, challenge prototype and pre-production testing.

This project is managed by the Dutch National Road Authority at the Ministry of Infrastructure & the Environment. Other participators are the National Swedish Road & Rail Authority and research institutes from France and the Netherlands.

The ground breaking idea in this project is to keep using existing standards in GIS & BIM but also keep the information linked. The foundation for achieving this is envisioned to be via a linked data approach through the semantic Web.

It is a very ambitious project and is very technically challenging. V-Con aims at enabling national road authorities to introduce software tools for exchanging/sharing comprehensive road information with commercial parties in the sector.

The author is responsible for designing SWECO's solution idea that was selected in competition with 14 proposals and further developed in phase 1 of the PCP-process. The solution idea has now qualified for phase 2 of the project - meaning that challenge prototyping will begin January 2016. In short, the solution design consists of designing modules adding Semantic Web capabilities to a standard Spatial Data Integration platform (FME by Safe Software). This platform already supports reading and writing most BIM and GIS standards but currently doesn't have Semantic Web functionality. Adding these new Semantic Web capabilities to an already wide spread integration platform will hopefully increase the chances of the Linked Data approach to be adopted throughout the industry.

If the prototype meets the challenges in phase 2 it might be a candidate for pre-production testing towards the end of 2016. After this it can be released as a solution for the market.
The V-Con project is one example that may pave the way to broad application of Smart Cities and Geodesign solutions. We need more such initiatives in all affected sectors of our society in order to make BIM and GIS databases better connected and help the vision of really Smart Cities.

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