IMMERSIVE CONCEPTUAL DESIGN IN A 3D CITY MODEL

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ABSTRACT: *Facing the challenges of aging infrastructure, the search for better renewable energies and growing population in cities, Government agencies, municipalities and utilities are looking for more accountability, risk mitigation and collaborative decision making around investments in infrastructure design and construction. Often, what's requested by stakeholders is a better overall process to understand, experience, and collaborate around infrastructure development while balancing the demands for sustainability with the need for economic growth and livability.*

For many stakeholders, an accurate 3D city model can help design professionals, agencies, and public stakeholders alike understand the impact of projects more intuitively than can 2D plans. The visually immersive presentation and interaction (interactive 3D navigation, manipulating, annotating, publishing, collaborating and distributing information "on-demand") of 3D models can help to meet these challenges.

Infrastructure planning processes typically involve several parties, from designers, agencies, and public stakeholders. Collaborative processes require that information is available from different platforms at any time. Collaboration includes the ability to markup and comment so that reviewers can share feedback with designers, as well as the ability to allow teams to improve efficiency by distributing design across communities of editors. Cloud-centric workflows enable users to enhance the process of collaboration throughout the planning process, such as comments and collaboration, in order to achieve a more confident and sustainable decision on infrastructure design and construction. This means being able to pass information, connect to the team or doing editing work on the same dataset using the internet connection to reach the model stored in the cloud. Moreover, 3D models enable all stakeholders to stay on the same page regarding proposed development, because of the more natural, intuitive way for communicating with non-technical stakeholders.

Besides the collaborative environment the way those 3D models are visualized are important in terms of acceptance. Based on even simple GIS and CAD data the look and feel should be as realistic and immersive as it can represent the reality as it is or as it can be.

KEYWORDS: *infrastructure design, conceptual design, 3D sketching, Cloud-centric workflows, Collaboration, 3D modeling, immersive visualization*

1. INTRODUCTION

Infrastructure projects are all around us and affect people every day. Planning new or enhancing existing infrastructure assets or networks becomes a more and more complex job then in the past. What makes it so complex and why are we facing so many projects nowadays? This paper looks at the reasons and challenges of today to find out where exactly virtual 3D model applications can help to design and evaluate infrastructures before they get build. Autodesk provides tools for the AEC market and launched the BIM concept throughout the Architecture world. With Autodesk® InfraWorks™ (Fig.1) we are looking at tools which provide the BIM concept for infrastructure projects in order to cope with the raising demand to modernize our urban infrastructure world.

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Fig. 1: So where is the need of rebuilding and offering of new infrastructure coming from and what are the challenges which are faced by tackling today's infrastructure projects?

1.1 Exponential Urbanization and scarce fossil fuel resources boost Infrastructure Investment

Buildings, utilities, and transportation systems are facing a tremendous challenge from the exponential growth of urban population as well as an increased use of renewable energies over fossil fuels. Aging infrastructure is an issue occurring everywhere from underdeveloped countries up to the leading economies of the world. Government agencies, municipalities and utilities are looking for accountability, risk mitigation and collaborative decision making around investments in sustainable infrastructure design and construction. With respect to the amount and complexity of today's infrastructure projects as well as the anticipated short time frame for their realization there is a strong need for effective tools and data management throughout the life cycle of infrastructure projects.

Providing proper tools and services, organizations will need to look at infrastructure business trends and the resulting challenges.

1.1.1 Population growth and urbanization

"The World Economic Forum estimates that we will have to build the same urban capacity (housing, infrastructure and facilities) in the next 40 years that we have built over the past 4,000 years in order to meet the demand arising from this unprecedented urbanization." (Geoff Zeiss 2012). This indicates a tremendous demand and the need to develop and maintain infrastructure at an unprecedented scale. According to United Nations Population Fund more than half of the world's population is living in towns and cities. "By 2030 this number will swell to almost 5 billion, with urban growth concentrated in Africa and Asia. While mega-cities have captured much public attention, most of the new growth will occur in smaller towns and cities, which have fewer resources to respond to the magnitude of the change." (UNFPA 2007)

1.1.2 Sustainability: New ways of energy generation and distribution

Sustainability crosses nearly every section of human activity today which is affected by energy consumption.

Within urban regions where thousands of people live energy plays an important role. With fossil fuel resources becoming scarce and the continued shift from nuclear power, the general consensus is that we need to find new ways to generate energy. Looking at solar power plants and wind parks on one hand and the existing infrastructure on the other, it is obvious that those networks need to be replaced to cope with all of the new energy resources, including the location of these resources relative to the populations they serve (e.g. often wind farms are located far from the cities they serve).

Scare resources are more or less a kick off to look at more resilient energy distribution and overall operational cost effective energy production. At the same time the result should be a much cleaner environment where new infrastructure integrates smoothly into.

1.1.3 Large investment in infrastructure

The biggest problem is the financial investment to maintain existing and develop new infrastructure in a way that the investment turns into sustainable environmental, economic and social growth. Many countries spend huge amounts of money to stimulate their respective markets. In 2012 Germany alone spend $33.3365M for Infrastructure out of $3.006.800M GDP (CRP 2013). "Just keeping pace with projected global GDP growth will require an estimated $57 trillion in infrastructure investment between now and 2030. That's nearly 60 percent more than the $36 trillion spent over the past 18 years…" (McKinsey 2013)

As shown above there is a strong need to invest in infrastructure projects to compete against the pressure arising from urbanization and changing energy paradigms. “Getting it right with cities and infrastructure has significant potential, not just from a pure economic perspective, but also from a social and environmental sustainability perspective. Getting it wrong is likely to be very costly socially and environmentally” (Ken Henry 2010)

Let’s have a quick look at the resulting challenges, which drive the requirements for virtual reality applications.

1.2 Business challenges

The key business challenges in all of this is that organizations need better processes to understand, experience, and collaborate around infrastructure development while balancing the demands for sustainability with the need for economic growth and livability. Stakeholders are dealing with a situation where project requirements are increasing while budgets decrease. To address these challenges organizations must enhance coordination and collaboration efforts by utilizing the cloud and open access to data.

1.2.1 Increasing project requirements with shrinking budgets

Projects are much more complex but require planning and decision making based on various requirements in a short time. This as well as shrinking budget, puts many AEC firms in the position whereby they are using the latest technology to drive productivity and handle the complexity of infrastructure projects.

1.2.2 Centralized Data

As mentioned above the complex structure of projects in the infrastructure domain relates to different kind of data. It is essential that every necessary data set is accessible to stakeholders working on a project. Centralized storage for the most updated version of a dataset provides fast access and can be used for meaningful analysis and decisions early in the planning phase of any project.

1.2.3 Efficient coordination and collaboration

Efficiency throughout the entire life cycle of an infrastructure process is mostly based on coordination and collaboration. Stakeholders must be on the same page from day one and communicated with in light of project proposals. Visual deliverables can address costly design conflicts, milestones, schedules and versions before the construction begins.

Infrastructure planning processes typically involve several parties, from designers, agencies, and public stakeholders. This anticipated collaboration means that information is available from different platforms at any time. Bent Flyvbjerg points out that mostly misinformation within complex infrastructure projects cause a tremendous deviation to the originally cost estimate. Within his researches he found out that nine out of ten projects have a cost overrun, where this relates to twenty nations across all continents and did not improve over the seventy-year period covered by the study (Flyvbjerg 2005).

Streamlining the whole workflow to be more effective makes a lot of sense. “It will be necessary to speed up approval processes, invest heavily in the early stages of project planning and design, and structure contracts to encourage time and cost savings (McKinsey 2013). It needs tools to provide those workflows which are capable of it. Building Information Modeling has been successfully established in the architecture domain – can this be an approach for infrastructure?

2. BIM FOR INFRASTRUCTURE

3D visualization is a more natural, intuitive medium for communicating with non-technical stakeholders as Geoff Zeiss pointed out. A realistic 3D model can help design professionals, agencies, and public stakeholders alike understand the impact of projects in a far greater way than that of 2D plans.

Building Information Modeling (BIM) describes workflows for creating an electronic model – in 3D – of a facility for the purpose of visualization, engineering analysis, conflict analysis, cost engineering, budgeting and many other purposes (Fig. 2).

“Engineers and owners developing infrastructure projects are facing unprecedented challenges—lower project funding, design complexity, economic uncertainty and public resistance to major infrastructure projects. Expanding our Building Information Modeling solutions for infrastructure can help our customers in transportation, water, energy, and land development segments to overcome these challenges—saving time and money and improving margins on projects,” said Paul McRoberts, vice president, infrastructure product line group, AEC solutions, Autodesk.

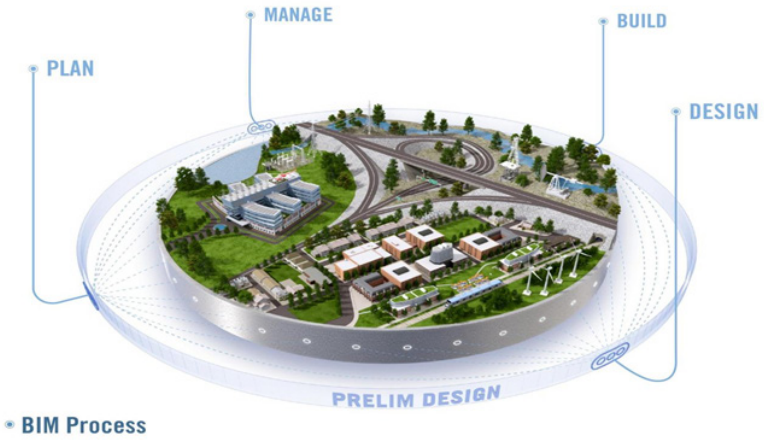

Fig. 2: Infrastructure Life Cycle, Autodesk

Increasing productivity for a much better and faster decision making will be facilitated through the combination of geospatial and 3D technology as well as BIM to rehabilitate the aging infrastructure.

3. HOW SOFTWARE CAN HELP TO OVERCOME THE PLANNING AND MANAGING DIFFICULTIES WITHIN INFRASTRUCTURE PROJECTS

Effective planning and design saves time and budget, seeds trust in the decision and communicates with a broad group of stakeholders. Let's look at some features that can be used to help overcome the challenges of planning, designing, constructing, and managing infrastructure.

Big Data

When working with and in 3D models the amount of data is significant higher than found in most 2D drawings. Depending on the Level of Detail, the spatial extend and visual effects infrastructure model sizes reach GB of data, which needs to be handled efficiently.

Apart from the classical Desktop application with a good set of hardware settings we are looking at a totally different landscape today. As a stakeholder, designer, project manager or planner I want to be able to access from and publish my model to different clients (Web, Tablet, Desktop, Smartphone) on different platforms (Win, IOS, Android…). I also want to manage my model content, such as rules, styles, models from anywhere I have access.

So, how does this help with the challenges mentioned above?

If all project related content can be handled across the project team in a way that size does not matter work can be much more efficient. There won't be version of something except the model, which is the base of all decision making. This needs the willingness of providing the data at a central place.

Integrative BIM for infrastructure

BIM for infrastructure deals with assets from the architecture, engineering, construction and GIS worlds. In terms of an integrated process BIM ensures that data and metadata can be shared throughout the infrastructure life cycle from conceptual design, through detailed design and construction as well as operation and maintenance.

So, how does this help with the challenges mentioned above?

When creating a new design one usually keeps initial drawings until new designs take their place. Once a design is accepted it can be easily transferred into another tool (AutoCAD Civil 3D or Autodesk Revit) for the detailed design. All relevant information can now be accessed and detailed can be added. The output of the detailed design phase typically includes a 3D infrastructure model from Autodesk InfraWorks that can be used to validate designs created via other design tools, like Civil 3D or Revit.

The benefit of this integrated model-based design approach for infrastructure is that rich information can be created and shared from the beginning without recreating content.

Easy to use, workflow/persona based

The user experience is one key to success as it describes how a user interacts with an application in order to get work done in a more efficient way. Currently, most professional software for planning, designing, and managing infrastructure is of the monolithic desktop variety and can only really be used by trained professionals. Since time and money are the limiting factors planners, stakeholders and designers need to be able to enter workflows and content which are appropriate to their work as well as from anywhere no matter if they sit in front of the desktop or on their way with a tablet – via a simple user experience.

So, how does this help with the challenges mentioned above?

Different personas within a project have different focuses. Most of them will never use all of the functionality the professional software provides or nor will they use the best and effective workflow since the software's user interface likely does not make it easy for them to do so. The answer: imagine a designer logs into a cloud-based system and based upon his credentials the software ecosystem knows establishes his/her identity and role as well as which content and functionality maps to that designer helping them get their work done more effectively.

Using cloud for services, communication (sharing, feedback) and collaboration

Infrastructure projects are much more networked than any other time in history. Decisions need to be made based on the same information across distances and disciplines. Distributed teams must be able to collaborate without sending copies around, further replicating data that is already out of date.

In our private daily lives we use cloud technology to connect to people, store and share information, stream music and videos, as well accomplish other tasks that are difficult without being connected. Technology provides huge potential to spread work, date and tasks across the network to the people who need that information. Infrastructure planning ideally participates from cloud centric workflows to ensure that all stakeholders are kept up to date.

Communication is the key to this and is also where infrastructure modeling starts. If a model is stored in the cloud and can be reached from different stakeholders, everyone is on the same page and can contribute by giving feedback, marking certain issues or even creating new content.

A second huge potential of the cloud is the idea that it can provide services that perform tasks more efficiently than humans can on solitary desktop machines. Resources can be used which are not at your reach in order to provide a simulation or analysis no matter which device you are using.

So, how does this help with the challenges mentioned above?

Staying on the same page using an always up to date model and having the chance to directly stay in contact with team members is a priceless advantage in investing the rare time and budget more efficiently. Cloud-centric workflows enable the users to enhance the process of collaboration throughout all stages of the planning process, such as comments and collaboration, in order to achieve a more confident and sustainable decisions. Moreover, 3D models enable all stakeholders to stay on the same page regarding proposed developments.

Create parameterized conceptual design

Infrastructure projects are of big interest in general. There are many dependencies where projects can fail, as explained in the aforementioned examples. Nearly every one of us plays a role in construction projects when stepping out of the door each morning. This means that stakeholders within a project are so divers in consuming the ideas about what "can be" that it would take ages to communicate in a proper way to every involved group. As mentioned before a 3D representation of the world outside drives a common understanding of we know and look at a 3D model evokes a more natural understanding of proposed changes in the existing world.

The "what can be" is now evaluable compared to the existing infrastructure to all stakeholders also the non-technical. In this case 3D is the rule.

In the conceptual planning stage you would want to set certain parameters to get assumptions according to project related requirements, for example sketching a road. The way a road needs to be designed depends on the assumption if it behaves as a highway or a local road towards its angles, slope and rise. Perfectly a designer would choose a road type where previously set parameters from local requirements are defined, which helps him to sketch within these boundaries (Fig. 3).

So, how does this help with the challenges mentioned above?

Again, looking at the constrains of a small budget, less time, complexity and addressing diverse stakeholders the first sketch should be quick, representable and according to local or project requirements. This workflow prevents project members to recreate content to communicate, adjust proposals to assumptions manually and dumping time and money to create a proposal.

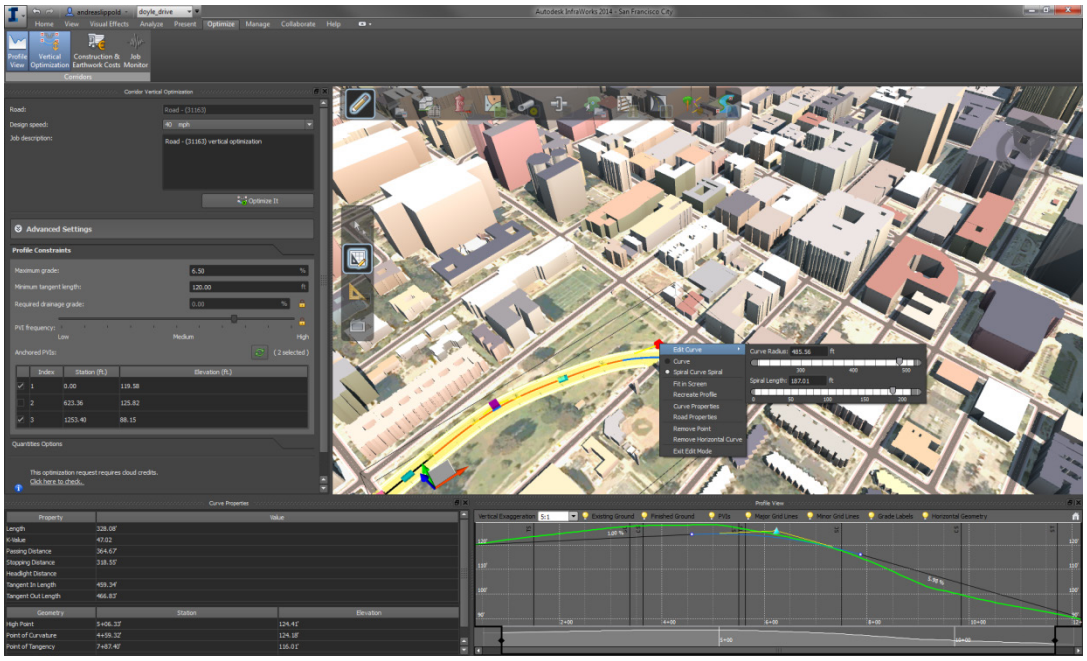

Fig. 3: Designing a civil road in InfraWorks 2014, Autodesk

Immersive visualization

Besides the collaborative environment the way those 3D models are visualized are very important in terms of acceptance. Based on even simple GIS and CAD data the look and feel should be as close to realism as it can be to get the impression of "what will be" in the context of is already there.

There are two ways to provide a realistic look and feel of a virtual 3D model. On one hand a building for example can be visualized as a simple block in order to capture the 3D building extend. Shaping out the details of a building in terms of façade, roof and even interior design can drive the acceptance for a planning because of the detail or lets the viewer recognize where he is located by realizing the context by its details. On the other hand it depends much on the correct light, reflections and realistic behavior of nature (sky, water) to wash-out away the borders between the virtual world and reality. A realistic representation is shown in the example of San Francisco in Fig. 4.

Fig. 4: Downtown of San Francisco in InfraWorks 2014, Autodesk

So, how does this help with the challenges mentioned above?

Infrastructure projects are successful if they are accepted broadly. This results out of a good communication with all stakeholders, right from the beginning based on an immersive and realistic 3D infrastructure model. It certainly make a difference if you see a blue polygon where the label says it is a water areas or if you see a water shaded surface where the sun and other infrastructure assets are reflected. It makes a difference if you see a gray block or a block with light maps and shade to represent a cube in a realistic environment and time.

The understanding and acceptance rises if stakeholders face something more realistic and not game like. The benefit for the project lays in the shorter decision making phase since all anticipated groups and stakeholders are informed in a natural way by a representative 3D model to understand, discuss and evaluate the early design.

4. AUTODESK® INFRAWORKS™

The introduction of BIM has changed the way architecture companies work. With BIM for infrastructure Autodesk is going to address the whole AEC world lifting the BIM approach to the scale of infrastructure projects to face the above mentioned challenges.

With Autodesk InfraWorks AEC firms can"…quickly and easily create infrastructure design models. Accelerate the design process, and enhance understanding of project constraints for better decisions. Generate data-rich proposals to better predict how design alternatives may perform in the existing environment and more effectively communicate with stakeholders" (Autodesk.com).

Today InfraWorks enables the user to model existing infrastructure form CAD, GIS and 3D model data and visualize them in a realistic way.

Powerful design tools provide the option to sketch out early design proposals which can be verified and exported to AutoCAD Civil 3D.

The visual appealing proposals can be shared through the cloud in order to work collaboratively on a project, publish scenarios through I-Pad and Web viewer as well as create videos based on various options to run through your model and pop up information as you go.

This short summary of Autodesk InfraWorks shows how a tool may help to create and communicate complex infrastructure projects easily in a visually understandable way and share it across tools, platforms and stakeholders. To cope with complex projects in a short time and deliver output to various interest groups and internal project workers AEC firms need a set of tools which easily adopts to certain workflows and roles in order to be efficient and fast. This cannot be accomplished by a monolithic desktop solution rather than an ecosystem out of services, application and toolsets.

InfraWorks is a new invention and needs to prove if the concept reaches the industry in the way it is meant to be. The feedback so far from the civil engineering companies shows a strong adoption of InfraWorks since they are able to sketch out a detailed idea easily as well as using the initial design further on within the detailed design phase. Today the key element to success hereby is the way to create a design in 3D based on certain assumptions very quickly and being able to communicate this broadly. Current CAD application cannot provide the context (large scale), cannot offer a quick concept sketch and providing a natural view on things is rather tough to generate.

Looking ahead InfraWorks should be able to address different assumptions which come along with a new design and need to be analyzed or simulated within the new planning's context. It does not make much sense if a proposal looks good but based on the given constrains and requirements it cannot be build. If this pops up in the detailed design phase then the project ends up as we can see it in many present examples, costs will explode and time will pass. Starting already today with cloud based services to calculate optimized profiles, or setting rules and constrains for certain road types is the way InfraWorks gets enhanced in the future to make sure a proposal gets as solid as it can get to be built under the acceptance of all stakeholders.

When looking at InfraWorks we do see an ecosystem of tools which provides a platform for Stakeholders, Planners, Civil engineers and everyone who is involved in infrastructure changes. There shouldn't be a monolithic desktop providing unlimited functionality rather than only the tools which are needed to slim the process of creating, analyze, simulate or present content.

5. SUMMARY

Facing a tremendous demand of extending and building new infrastructure today, the expectations on tools have changed. 2D sketches and plans are consumable by only a certain group of professionals. Technically not so skilled

stakeholders need to have a different view on things they see within the 2D plan. The public is more engaged when it comes to bigger infrastructure projects and wants to take part in it, want to explore it.

3D city models have become a part in city marketing and municipalities are more often considering those models to be part in a decision making and informing process.

Given the short timeframe and the smaller budget planning has to be faster, more efficient and easy to understand by various stakeholders in order to achieve the best possible design, without entering a redesign phase later in the project.

Complex infrastructure projects designed and handled in 3D, data size matters when it comes to share simulate or analyze. Cloud centric workflows are perfect when it comes to highly intense tasks which can hardly be solved on a single desktop. Making a model available to the whole group involved in the project across distances can be tough without a cloud storage which intelligently synchs and provides easy access to the model, to the group and the content.

The main challenge in today's infrastructure world is to save time and money during decision making without leaving stakeholders outside of the process. Autodesk® InfraWorks™ today shows how a software ecosystem can easily be used to create a model where planning is made upon. Initial planning process need to be in 3D to reflect as realistic as it can the new scenario to a wide group. Parameterized sketching with highly realistic styles are used to create the scenario very quickly as well as sharing it right away.

These are the credentials to come up with a quick idea to be evaluated throughout a stakeholder community with respect to shorten the process of creating different proposals as well as deciding on certain proposals. This can save time and money, because everyone is on the same page and the detailed planning stage can be entered with a properly evaluated design which does not need a recreation from sketch.

BIM for Infrastructure can be the process to align the whole workflow of an infrastructure life cycle and applications like Autodesk® InfraWorks™ are providing some of the functionality already today.

Looking ahead, 3D will be the way to go. On top of a growing number of 3D city models there will be different kinds of applications to plan, to publish, to analyze and to simulate as well as making it easy to collaborate on a model. In order to cover all functionality you will need the internet technology to provide services, request for calculation power and connecting to your stakeholders. It will be a strong shift from monolithic desktop solutions towards an ecosystem of tools that enforces project planers intuitively do their work in a natural but professional way.

6. REFERENCES

CRP (2013). http://www.crp-infotec.de/01deu/finanzen/bundeshaushalt_aktuell.html

Flyvbjerg (2005). Policy and planning for large-infrastructure projects: problems, causes, cures; Environment and Planning B: Planning and Design 2007, volume 34, pages 578 – 597;
http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2230414

Henry, Ken (2010). To Build or not to Build: Infrastructure Challenges in the Years Ahead and the Role of the Government: Address to the Conference on The Economics of Infrastructure in a Globalized World: Issues, Lessons and Future Challenges;
http://archive.treasury.gov.au/documents/1763/PDF/Infrastructure_Conference.pdf

McKinsey (2013). Infrastructure productivity: How to save $1 trillion a year,
http://www.mckinsey.com/insights/engineering_construction/infrastructure_productivity

McRoberts, Paul (2012). BIM for Infrastructure, Infrastructure Product Line Group, Autodesk

UNFPA (2007). Urbanization: A Majority in Cities, http://www.unfpa.org/pds/urbanization.htm

Zeiss, Geoff (2012). Convergence, interoperability and standards, Autodesk,
http://www.opengeospatial.org/blog/1591