

# **10 Years of Development in Model-Based openBIM Workflow in Infrastructure Surveying in Finland from a Surveyor's Perspective**

**Miika KOSTAMO and Petteri PALVIAINEN, Finland**

**Key words:** Surveying, Civil Engineering, Infrastructure Construction, Machine Control

## **SUMMARY**

Infrastructure construction has rapidly transformed from old paper-based processes to model-based process in Finland in the last 10 years. Finland was the first country in the world to publish its Common InfraBIM Requirements in 2015 and since has been one of the leading countries in the world developing model-based construction processes in the sectors.

In this text the authors try to highlight some of the main changes from a surveyor's perspective and the factors that have made the change possible. From the surveyor's perspective the same core measurement and positioning principles still apply to model-based working, but at the same time new requirements and new data user needs demand adaptation to new ways of working.

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## **1. DEVELOPMENT OF COMMON INFRASTRUCTURE MODELLING REQUIREMENTS**

The development of common infrastructure modelling requirements in Finland was initiated back in 2010 as part of Built Environment Process Re-engineering – PRE project. PRE itself was a combined industry effort to re-engineer the whole design and construction process for the construction industry.

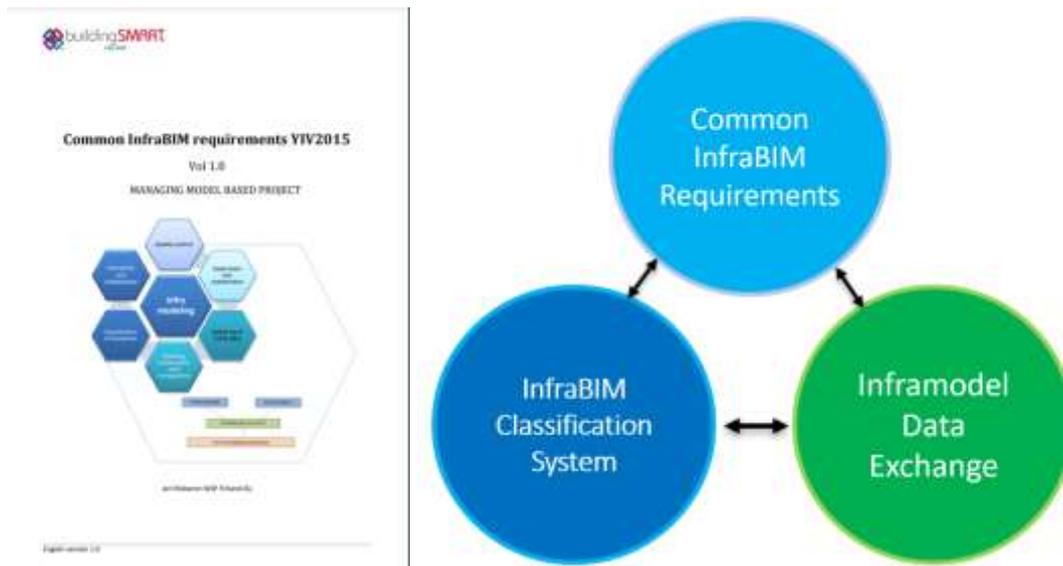
In the project 37 companies and 6 research institutes took part in the process and total investment was 21,8 million euros for the development of new BIM based working processes and business models during the 4-year project. Infrastructure development part of PRE was studied under the working package INFRA FINBIM. In which 17 companies, major infrastructure owners including Finnish Transport Agency, major cities and 3 research institutes took part.

The target of the INFRA FINBIM working package was to create a new BIM based design and working process for the whole infrastructure industry, so that same BIM processes and data formats could be used in through the whole lifecycle of the industry. During the 4 years of PRE project the new model-based workflows for infrastructure were tested in several trial project to verify the outcomes as well as to see, how the new methods could be applied in real-life. Model-based workflows were also matched with new cloud-based data management solutions and machine control systems were applied on worksites to enable fully digital data flow from design office to the handover of the project outcomes.

During the project it became clear that to enable fully digital and standardized process, also common rules and guidelines for the process would be needed. With common classification system, data format and BIM guidelines it would be possible to create a common process for the industry, which would also remove many of the complexities and variations that existed before the PRE project in the industry's practices.

The many outcomes of the PRE project are too wide to analyse in detail in this text and can be read from the references, but regarding the model-based construction in the infrastructure sector the most important outcome from INFRA FINBIM development was the Common InfraBIM Requirements for the industry. When the PRE project ended in 2014, this outcome was handed over to buildingSMART Finland, which in the past had also developed Common BIM Requirements for the building construction industry in Finland.

## 2. PUBLICATION OF INFRASTRUCTURE BIM GUIDELINES IN 2015



Common InfraBIM Requirements, InfraBIM Classification and Inframodel Format.

The Common InfraBIM Requirements YIV2015 was published in the spring of 2015 and became the first openly published openBIM guideline for the infrastructure sectors in the world. The requirements consisted of 3 main parts, which were the InfraBIM guideline, Inframodel data format and InfraBIM classification system.

The guideline itself included the different stages of the design and construction process including initial data gathering, infrastructure modelling practices, coordination and interaction principles, construction planning, quality control and supervision/coordination responsibilities in InfraBIM projects. In scope of the content the new YIV2015 guideline were already wider than many other similar guidelines or industry modelling instruction, which in most cases still today focus on the format definitions or data transfer requirements.

Soon after YIV2015 was released the major asset owners participating in the INFRA FINBIM working package also started to demand its use in their projects, which was also a key milestone in adapting to the new ways of working and boosted the demand for the new way of working.

This change happened early in Finland as the major infrastructure asset owners had already seen the benefits of standardized openBIM processes in comparison to the old way of doing things in the past, when each company and asset owner had had their own demands and preferences, which in most cases had not taken in consideration the productivity of the whole industry.

For the surveyor release of the new InfraBIM requirements meant, that finally majority of the clients in the infrastructure sector had same data content and format requirements instead of the hundreds of organization specific requirements that had existed in the past.

The new YIV2015 guidelines also included the common definitions of coordinate systems, height models and survey control networks, so also this aspect made the surveyors tasks easier.

## 2 SURVEYOR'S PERSPECTIVE TO THE INDUSTRY TRANSFORMATION

From the surveyor's perspective the industry transformation brought new things to learn, but it also simplified many old practices especially, what comes to organization specific demands.

After the YIV2015 became a demand from the largest infrastructure owners in Finland, it meant that over 50% of Finnish infrastructure projects required the same surveying practices, same data content, format and same coordinate references, from that point forward.

Making things fully digital with common data standards also meant that surveyors were not anymore required to hammer or paint every single stakeout marking to the ground. New digital solutions became feasible options for the whole industry.

With digital design models, it was possible to use these models directly in the machines fitted with machine control systems, so the additional physical markings in the field were not anymore needed. This was also the most visible change in the process and infrastructure project locations could not be any more defined by the hundreds of wooden stick standing on construction sites.



Helsinki Airport expansion project with model-based workflow, photo by Tero Maijala.

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In the new model-based workflow, instead marking out with physical of stakeout sticks, the quality-controlled models were transferred from the project office directly to machine control systems in the field. Making latest design data available for the machine operator with just few clicks on the touch screen.



Inframodel format road design seen on a machine control system screen in an excavator.

For surveyors this also meant less repetitive visits to the same project location as there was no need to mark every layer of the construction separately. With Inframodel format including layer definitions next layer construction could be selected by the driver with an up or down arrow.

This did not completely remove the surveyors tasks on typical infrastructure construction sites and the most precise measurements are still done by surveyors, but it reduced the amount of time spend driving around construction sites and improved the overall flow of the process as work could continue without surveyor checking every step of the process separately.

Surveyors still today on most construction sites are responsible of all construction measurements, which are not done with machine control systems, as well as the overall

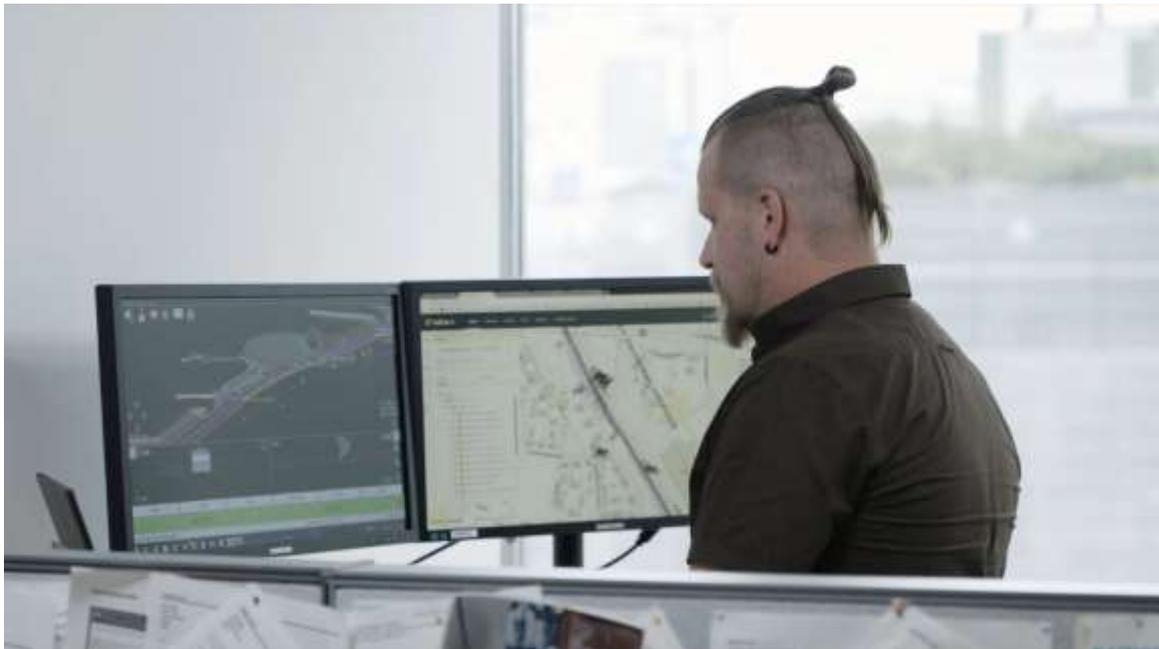
survey control and quality assurance/control for the process. For the surveyor this meant that less sticks were hammered in the field and more use of his or her surveying know-how as with increased model use also more people were dependent on correct coordinate definitions and quality assurance in the digital process.

### **3 FROM PAPER-BASED TO MODEL-BASED CONSTRUCTION**

A less visible change from the outside is the data management on site. In traditional construction sites most, designs were communicated to all the necessary parties on construction sites by providing them a paper copies of the design files. Every time there was on design update new drawings had to be printed out and shared for all necessary parties on site, which sometimes could take days from the original design change.

In model-based workflow the paper copies are not anymore needed as the design data is directly usable in the surveying equipment or in the machine control system. Same Inframodel file, which is used in the office to check designs or to communicate next phases of the construction, can be also used by surveyors and machine operators on the field. This also reduces the time needed to distribute new information as well as allowed using cloud-based solutions to track, which information has been shared, when and to whom.

Only step between the design office and the machine control today is the quality assurance for the model in the field office. Purpose of this step is to ensure that the new model also fits with other models in the same area of the project.



Tampere Tramway project survey manager checking models for machine control.

This might seem small but knowing how many design changes do happen in infrastructure construction, it is a major change in the process. Still today the major reason for infrastructure projects is the surprises found underground.

In traditional paper-based project getting new approved paper copy of an altered design can take weeks. In model-based workflow this can be achieved sometimes within the same day. Communication is also a lot easier, when all parties in the project look at the same file version and not variable copies or presentations of the original design.

In Finland using the same Inframodel format, which in fact is an extended LandXML 1.2 version, for the design files, machine control models and as-built documentation has also allowed linking design files to as-built result of the construction. This has improved the quality of work, but also allowed on design file level to analyse different approaches to the construction process.

In model-based workflow each tasks can be linked to a specific model, which also leads to better understanding of the overall project situation and in case Tampere Tramway project even to daily reporting of the construction progress as completed tasks can be seen just right after the last point for the day is stored in the field.

#### **4 QUALITY CONTROL AND ASSURANCE IN MODEL-BASED CONSTRUCTION**

In model-based construction the quality and accuracy of the design model are the basis for good construction quality. For 3D machine control to work on site design models need to cover the whole construction site and plans need to match to each other on the borders.

As most design projects are split to segments or sectors it is common to have overlaps or gaps between designs. For models to be usable on the field these gaps need to be identified and models need to be matched to each other, so that those can be used as reference on the field. Also, possible zero height points and other mistakes need to be removed, before sending the data for surveyors or machine control systems.

If machine control is used on construction sites, someone also needed to verify that each used system has been calibrated correctly and use correctly defined transformations for the project. In practise this means comparing machine control measured points to surveyor's measured points within given accuracy limits.

Above mentioned verifications often require surveying and modelling know-how, and it has become a common practice in Finland that surveyors on-site have also become responsible of the model quality assurance process as well as supporting the machine control systems with coordinate definitions, model distributions, training the operators to work with right methods and data storage practices on model-based construction sites.

What comes to as-built measuring the current version of the Finnish Common InfraBIM Requirements YIV2019 defines the measuring interval measurements made with machine control systems for road cross-sections as 20 meters and the needed position accuracy for each construction layer. Same applies to surveyor measured controls in places, where machine control cannot be used or higher accuracy for the measuring points is needed.

YIV2019 guideline also requires additional quality control measurements to be done by a surveyor for every 50 meters for streets, every 100 meters for paths and smaller tracks and every 200 meters for railways or highways. Purpose of these measurements is to ensure from independent source that all the machine control measuring systems work correctly and to prevent possible errors or inaccuracies from affecting whole construction projects.

Projects using their own GNSS bases station the YIV guidelines require monthly checks for the base station and the that the base station control measurements results are stored and documented as well. In case the base station has moved it has to be re-calibrated and measurements onsite cannot be continued, before the new coordinates for the station have been published.

On site, where machine-control is used there is additional quality assurance processes for checking machine control system measurement accuracy. Requirement is that each machine must be checked once a week with a total station or GNSS measurement system to compare it to the instruments used by the surveyors onsite. These control measurements must be also documented, and no machine is allowed to work without a valid check report.

## **5 NEW ROLE FOR SURVEYORS ON INFRASTRUCTURE CONSTRUCTION**

Before the publication of the Common InfraBIM Requirements the surveyor's role and responsibilities on different infrastructure construction sites used to vary a lot depending on the companies involved in the projects. There was no common way of working before InfraBIM.

This became also evident after the first version of the Common InfraBIM guidelines were published as well as the fact that in model-based construction process a lot more people started to use the model data and depend on its quality and accuracy on their decision making. Surveying know-how became a must on model-based construction sites.

To tackle this problem, the second version of the Common InfraBIM Requirements in Finland, YIV2019, introduced a new role for model-based infrastructure construction sites in Finland.

This role is called Onsite BIM Coordinator and his or her responsibilities included:

- Quality assurance for design models used in construction phase.
- Management and distribution of construction phase design data

- Quantity take-offs and calculations onsite
- Model-based quality assurance onsite
- As-built and control measurements data management including distribution
- Design, construction, and management of the survey control network onsite
- Controlling and organizing the onsite measurement activities and requirements
- Preparation of the as-built documentation for the project handover

For many infrastructure surveyors these tasks might seem familiar even in paper-based processes and are in fact tasks that most surveyors have been doing even in paper-based construction processes. In Finland, the Common InfraBIM Requirements YIV2019 was still the first document that clearly defined these tasks as responsibility of the head surveyor onsite.

In model-based construction process, as the surveyor was not anymore needed to stakeout every single point on the field in person, this also meant that the surveyor's know-how on coordinate system, 3D models and measurement quality issues could be made to better use on the construction process.

## **6 EDUCATION AS PART OF THE INDUSTRY TRANSFORMATION**

No change in construction happens without the people being involved in it. This rule also applied to the transformation from paper-based construction processes to model-based infrastructure construction.

3D model has been part of surveyors lives in Finland since the wider spread of GNSS measurements in early 2000s speeded up the use of all 3 coordinate in field measurements. In sense surveyors were ready for the new 3D model-based infrastructure construction process even before it had been developed.

The alignment to the new model-based process, was also helped by the fact that many surveyors were participating in the original PRE project and were able to highlight the importance of coordinate systems and control survey networks as part of the model-based construction process. Without proper survey control network it is impossible to create accurate model of the real world or to present the digital design models in their planned location in the field.

Classifications system and code lists were also in wide use in Finland, before the Common InfraBIM Requirement, so the transformation to one InfraBIM classification did not require a lot of new learning but it made obsolete the need to learn hundreds of organization specific code lists and classification system, that had been the practise before InfraBIM.

What was new in model-based openBIM workflow, was the linking of additional attributes to the surveying data as well as the need for the surveyors to start educating others on site about surveying topics, like the basic of satellite positioning or explaining reasons, why the as-built

and control surveys need to be measured with given interval to create a complete as-built model of the site.

When considering the whole transformation process in Finland the widest need for new know-how in fact came from the machine operators, who in the past were used to rely on surveyor's pen markings in the field and paper printouts in the cabin. In model-based workflow they had to start using touchscreen-based machine control systems with satellite positioning and in some projects also started to become responsible for their own as-built measurements.

In Finland, this challenge was tackled first with company and project specific training, which enabled the use of the new model-based workflows on new sites, but this was not enough for the industry wide transformation. Since the release of the first InfraBIM requirements, new university courses have formed, model-based working has become a topic for new machine operator training and first vocational schools have started to also educate model-based working in the infrastructure and surveying study programs this year. After few years there will be no new graduates for the infrastructure field that would not have studied model-based construction as part of their curriculum.

## **7 CONTINUOUSLY DEVELOPING PROCESS AND FUTURE OUTLOOKS**

In 2010 most surveyors in infrastructure project measured points with codes. Today on infrastructure sites measured points already have connection to the layers and design objects, from which those are measured from and which makes it possible to visualize those with specific context.

From a surveyor perspective work on infrastructure sites is starting to remind a bit more GIS type of data collection, where measured objects have several attributes and properties. One indication of this development is the fact that buildingSMART International, home of openBIM standardization, and Open Geospatial Consortium, home of open GIS standards, have started to cooperate and published several memorandums in cooperation.

The new version of the international IFC openBIM format also include many infrastructure elements, so in the future there will be more ways to present infrastructure designs in globally accepted open formats.

Some of the development for this sector will probably also happen in the field that traditionally have not been considered as core of surveying business. For example ISO Technical Committee for Earthmoving machinery is currently developing a common data exchange format for machine control models. Also many other new technologies like AI, digital twins, linked data and machine learning are mainly developed outside the surveying field even many of those rely on data collected by surveying and methodology, which surveyors have helped to develop.

As the Greek philosopher Heraclius once said, “Only constant is the change” and for future of infrastructure surveyors this means interesting times ahead.

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## BIOGRAPHICAL NOTES

**Miika Kostamo** has Bachelor’s degrees in Land Surveying and Business Administration. He has worked in international surveying and mapping projects since 2006 and is currently responsible of international business development in Novatron.

Miika is also the co-chair of Airport Room in buildingSMART International and member of the Infrastructure Room in buildingSMART Finland. In ISO TC127 he is member of the working group developing worksite data exchange standard for earth-moving machinery.

**Petteri Palviainen** is a trained cartographer with over 25 years of experience in the infrastructure construction. He has been part of the digitalization process of the infrastructure sector in Finland since 1990s and is very passionate about developing new working methods for the industry.

Petteri works now as the director of Novatron’s Digital Infrastructure Services department and manages the company’s participation to the international standardization processes. He has been part of the PRE project and its INFRA FINBIM working package, member of CEN TC422 and active participant in the development of Finnish InfraBIM standards including the Common InfraBIM Requirement version YIV2015 and YIV2019.

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