Benefits of Open InfraBIM – Finland Experience

R. Heikkilä[a] & T. Kolli[a] & T. Rauhala[b]

[a]Civil Engineering Research Unit, University of Oulu, Finland
[b]Novatron Oy, Finland

E-mail: rauno.heikkila@oulu.fi, tanja.kolli@oulu.fi, teppo.rauhala@novatron.fi

Abstract

The achieved benefits of Open Infrastructure BIM in Finland have been studied. The newest concept of Open InfraBIM in Finland is introduced. Industrial experiences and observed remarkable benefits in three large-size infrastructure design and construction projects carried out in 2012-2022 are presented and evaluated. Based on the observations and achieved results, the implementation of the Finnish Open InfraBIM concept has been successful in Finland. Clear benefits were observed and measured in three considered major design and construction projects. Most benefits were found from the latest project Kirri-Tikkakoski with remarkable cost and time savings. The benefits of BIM based machine control and real-time quality control were emphasized. This project has also used the most advanced and widest InfraBIM concept with early integration with all relevant stakeholders. Further development, information sharing and wider utilization of the Open InfraBIM in Finland and globally are suggested.

Keywords – Benefits; Model Sharing; Open InfraBIM; InfraBIM Requirements

1 Introduction

1.1 Background

BIM (Building Information Modeling) for transportation infrastructure has earlier been studied by Costin et al. (2018) [1]. The results showed the use of BIM for transportation infrastructure has been increasing with especially focusing on roads, highways, and bridges. Also they reveal a major need for a standard neutral exchange format and schema to promote interoperability. Benefit assessments were also found: the use of BIM instead of traditional documents was estimated to lead to economic and technical benefits. Also it was stated that application of BIM can help general contractors to reduce their risks and diminish the associated costs.

Dodge Data & Analytics (2017) [2] has provided a report of the Business Value of BIM for mainly infrastructure design phase. According to the study, the BIM implementation growth in especially US, UK, France and Germany has continued 2015-2019. Most BIM users (87%) have reported positive value from their use of BIM. Top business benefits of BIM related to transportation infrastructure projects have been such as (1) improving ability to show younger staff how projects go together (58%), offering services (56%), establishing consistent and repeatable project delivery process (54%), maintaining business with past clients (52%), and, less time documenting, more time designing (50%). As top ways how BIM has improved project processes and outcomes were found: (1) fewer errors, (2) greater costs predictability and better understanding of the project, and (3) improved schedule performance and design optimization. Based on the results, nearly two thirds (65%) believed that they can get a positive ROI (Return of Investment) from their BIM investment. In the previous publications, the detailed content of InfraBIM, i.e, modeling requirements, nomenclatures, open data transfer formats, as well as methods and applications utilizing these are not presented or described in more detail. [2]

Finland is not the only country in where infraBIM is utilized. Norway has a long experience of infraBIM, and this has been compared with projects in Vietnam [3]. Based on the literature, the business value of BIM for infrastructure sector has been evaluated in France, US, UK, and Germany [1]. In addition, the experiences of OpenBIM in infrastructure projects have been studied in Netherland by Bergs et al. 2016 [4], Russia by Boykov et al. 2020) [5] and Italy by Giovine 2019 [6]. In those publications, the concept and content of Infra BIM has not described at the level that Infra BIM is nowadays used in Finland.

Halttula (2020) has studied the benefits of early integration of BIM to infrastructure design and construction project. Halttula states that early integration of key stakeholders can lead to prompt and effective optimization of core competencies and knowledge as well as improves communication and decrease fragmentation. The product data model for the project should be designed in the early phase in collaboration with all relevant stakeholders, and also with client. [7]

Related to InfraBIM based machine automation and the benefits, Caterpillar (2016) has experimentally studied the benefits of utilizing 3-D machine control technology compared to traditional road construction methods. Infrastructure modeling was not considered. The benefits of the machine control technology were clear when considering the reduction in project duration, equipment hours, fuel consumption, total machine cost, operating hours, man-hours and total man-hours. Fewer machine hours protect machines from excessive wear, which reduces fuel consumption and leads to an environmentally conscious solution and reduced greenhouse gas emissions. [8]

Second Caterpillar workstudy was made 2006 in Malaga. The study measured productivity growth with AccuGrade 3-D machine control systems. In the experiments, two identical roads were constructed, one using traditional control methods and the second using 3D machine control systems. The lead times for all the different work steps were measured, the number of passes, buckets or truck loads, fuel consumption and also accuracy with these two different methods. According to the results of the study, the total working time required to build the road was 3½ days with traditional and 1½ days with 3D machine control. Fuel consumption was 43% lower with 3D machine control. [9]

In Finland, the development of Open Infrastructure Building Information Modelling (Open InfraBIM) concept has been ongoing since 2010 (Halttula 2020, Kivimäki et al. 2015), [7, 10] The large research work program RYM Process Re-Engineering (PRE) with Infra FINBIM work package was executed 2010-2014. Open Infra BIM means the concept that enables wide industrial utilization of model-based information at all stages of the construction process. [7,8]

The Finnish Open InfraBIM concept (Figure 1) includes three main parts: 1) modelling guidelines, 2) information classification system, and 3) open information transfer format Inframodel. The open concept has been specified down to detail and published by BuildingSMART Finland Infrastructure [11]. Building Smart Finland Infrastructure Business Group aims to develop and advange the use of infrastructure information modeling in Finland. The goal is to have fully digitized infrastructure design and production processes by 2025. [12]

The Common InfraBIM Requirements (the newest version YIV2019) cover the entire life cycle of an infrastructure project: currently initial material, different phases of design and construction including also as-built documentation. In the future, the aim is to add operation and maintenance to the requirements as well. The modelling guidelines aim to guide, harmonize and improve the modelling practices in the entire infrastructure sector. The guidelines are based on the current best practices, and they will be updated regularly as the knowledge and tools will be developed.

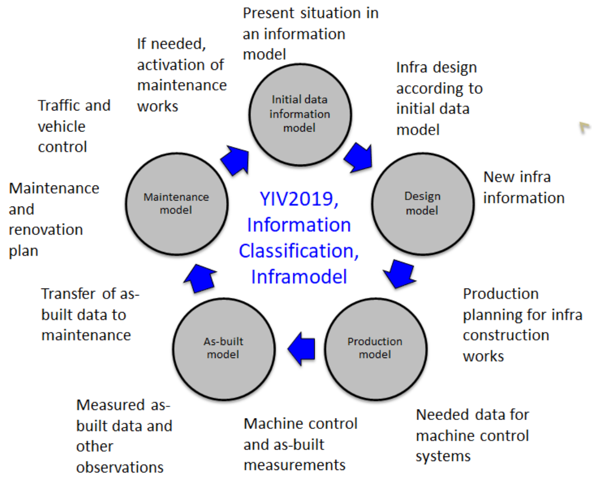

Figure 1. The Concept of Open InfraBIM in Finland (University of Oulu).

Inframodel is an open method for the exchange of infrastructure information. It is based on the LandXML standard. The Inframodel includes parts for terrain models, subsoil surfaces, road and rail geometries and construction layers. It also covers water sewage and supply and some facilities. The Inframodel documentation explains the Finnish method for using LandXML. Inframodel does not gather all the elements in LandXML – Inframodel is a subset of LandXML. On the other hand, some Inframodel specific extensions have been added to support machine readability needed. The most important of these is the Infra classification system. Inframodel is the exchange format required by the Finnish Traffic Agency and major cities since May 1st, 2014. Today, most of the main important client organizations, design offices and contractors use open and real-time cloud services Infrakit to share and utilize of open Infra BIM in different work phases of infra projects.

The InfraBIM Classification specifies the numbering and designation of infrastructures and infrastructure information models covering their entire life cycle (see Fig 2.). The purpose of the classification is to obtain a unified numbering and designation practice that serves infrastructures and infra-structure information models in every phase throughout their lifecycle: in obtaining initial data, design, execution, as-built surveys and maintenance. [13]

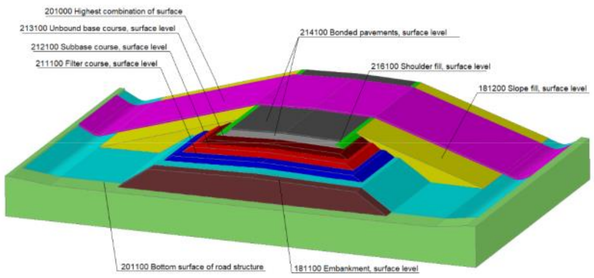

Figure 2. An Example of the InfraBIM Classification System (BuildingSMART Finland).

1.2 Aim

The aim of the research was to study the benefits of Open InfraBIM concept achieved among the selected highway and railway design and construction projects executed in Finland in 2012-2022. The sub-objectives were:

- to identify the BIM utilization level and main achieved benefits of Open InfraBIM in a few selected major infrastructure projects in Finland and assess their economic significance
- to find out whether the continuous development of Open InfraBIM is reflected in the increase of benefits in infrastructure projects
- to evaluate the usefulness and competitiveness of the Finnish Open InfraBIM concept compared to the concepts and measured benefits used in other countries.

2 Materials and Methods

2.1 Study about the use of Open InfraBIM in Finland

The following three major design and construction projects, (1) Kokkola-Ylivieska Dual Rail Design and Construction Project (schedule 2012-2018), (2) Railway Design and Construction Project Pasila-Riihimäki, 1th phase (2016-2022), and (3) Highway Design and Construction project Vt4 Kirri-Tikkakoski (2019-2022), were selected for closer interviews and studies about possible benefits by the use of Open Infra BIM. In this study, some selected key people in the projects were interviewed. In addition, sub-reports and evaluations of the projects were analyzed. In the (1) project the YIV 2015 modelling requirements were first implemented at large scale. There were widely utilized machine control systems (guidance-based control) for all the excavators, some implementations were also made and tested in road graders and compaction machines. Novatron was one example of company which provides machine control system that can open way be connected to cloud service such as Infrakit. The first version of Infrakit cloud service was used. During the (2) project the InfraBIM concept development was continued and further later utilized for the concept updating. In the (3) project YIV2019 was already utilized with also wider implementation of the real-time Infrakit cloud services for all the model sharing needed.

2.2 Kokkola-Ylivieska Dual Rail Design and Construction Project (2012-2018)

The Kokkola-Ylivieska dual rail design and construction project was implemented in 2012-2017 (Fig 3 and 4). The estimated cost of the project was € 330 million. The project built 80 km of new railways, repaired 80 km of existing railways, built 80 km of maintenance roads, built 20 km of new streets and roads, and built 80 new bridges and 70 culverts. The construction works of the intervals between Kokkola-Riippa and Riippa-Eskola were carried out as two separate sub-projects using the Design-Implement model. The last section, Eskola-Ylivieska, was split into smaller contracts: one electric track contract, which will be implemented with the Design Build model, one design contract, three substructure contracts, three superstructure contracts and the construction of the Vääräjoki bridge. The entire Kokkola-Ylivieska interval will be managed with one safety equipment contract. CC Infra Oy was the builder consultant for the project. The builder consultant was assisted by WSP Finland Oy under a separate agreement.

Figure 3. Kokkola-Ylivieska Dual Rail Design and Construction Project in Northern Finland – General Map.

Figure 4. Kokkola-Ylivieska Dual Rail Construction – The earthworks of the bridge sites were built using BIM model-based machine automation.

2.3 Railway Design and Construction Project Pasila-Riihimäki, 1th phase (2016-2022)

The Pasila–Riihimäki design and construction project (150 MEUR) improved the functionality of Finland's busiest railway section. The aim was to separate freight from passenger traffic and to make the connections at the main transport points faster. Several design companies and contractors participated in the project. All of them utilized Open InfraBIM as well as automated control systems in machinery. Most of them also used Infrakit cloud service.

The first phase of the Helsinki – Riihimäki project focused on improving traffic locations. In addition, an additional freight track was built to Kerava and an additional track to Järvenpää between Ainola and Purola. In the summer of 2021, a new interlocking device was introduced in Kerava to monitor the safe operation of trains, which is a prerequisite for the additional tracks to be built in the second phase.

The Open Infra BIM operation model in Pasila-Riihimäki project was as follows:

- the initial data model was provided by the owner/client
- InfraBIM requirements were written for the procurement
- continuous InfraBIM modeling and the utilization of models
- BIM model coordinators together, several consultants together with BIM coordinator
- InfraBIM modelling plan, operation planning utilizing BIM, BIM management
- continuous development and implementation of the BIM in several workshops with project staff
- implementation of the BIM plan with everyone in the project.

The evaluation with interviews was made by Netlipse organization (Network for the dissemination of knowledge on the management and organization of large infrastructure projects in Europe) on behalf of the Finnish Transport Infrastructure Agency (FTIA). [14]

2.4 Highway Design and Construction project Vt4 Kirri-Tikkakoski (2019-2022)

The Vt4 highway is one of Finland's most important heavy transport routes (see Fig 5). According to the FTIA, the traffic volume at Kirri in Jyväskylä was about 20,000 vehicles a day. Heavy traffic accounts for about 10 percent of this. The aim of building the motorway has been to improve traffic safety as well as uniform driving conditions, predictability of travel times and operational reliability.

The project Vt4 Kirri-Tikkakoski built a new motorway a total of 16 kilometers from Kirri in Jyväskylä to Tikkakoski and further to Laukaa Vehnia. In addition to the motorway, more than 20 kilometers of new roads and about 30 kilometers of new light traffic routes have been built during the contract. The design and development phase of the Kirri-Tikkakoski area began in the autumn of 2018. Construction work began in the spring of 2019. Destia was the main contractor in the project.

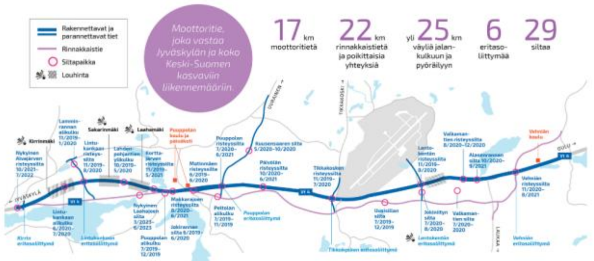

Figure 5. Highway Design and Construction project Vt4 Kirri-Tikkakoski (Finnish Transport Infrastructure Agency, FTIA).

3 Observations and Results

3.1 Kokkola-Ylivieska Dual Rail Design and Construction Project (2012-2018)

During the project, an interview survey was conducted for all different parts of the project, involving individuals from design, construction, and supervision. According to the survey results:

- 97% of respondents had been in contact with BIM
- 68% thought the data models had made the job of

design easier
- 69% said the turnaround time was faster in construction
- 55% answered that some or significant additional costs were incurred in the contracts due to BIM
- the savings from the use of BIM were achieved to some extent or by a significant 64%
- the quality of the design was estimated to have improved by 80%
- estimation of the quality of construction 93% of the respondents have improved data modeling

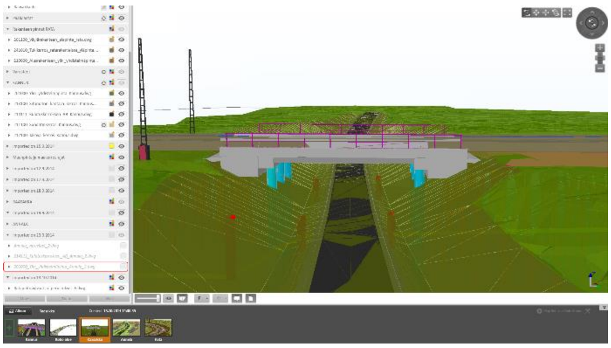

Figure 6. A Combination BIM Model Example of Kokkola-Ylivieska project.

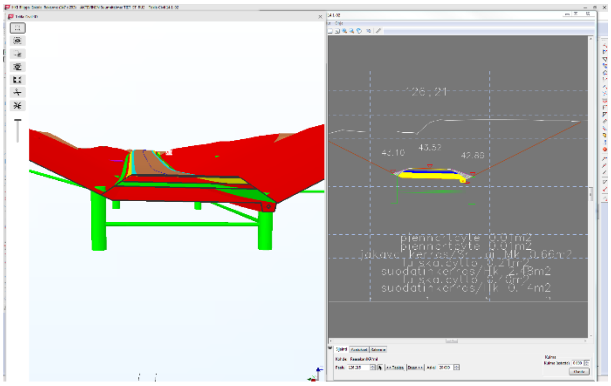

Figure 7. An Example of BIM model in Tekla Civil Design Software.

In the design, the greatest benefits were felt from more illustrative design, coordination of different types of technology and reduction of errors (see examples in Fig 6 and 7). In construction, there has been an improvement in quality in terms of both design and construction, as well as faster work. The cost has been somewhat increased by learning and developing new technologies and practices. The savings have been achieved through a reduction in errors, a reduction in waste and faster work. Software and the continuous development of operating methods were seen as important, as can see in Figures 8 and 9.

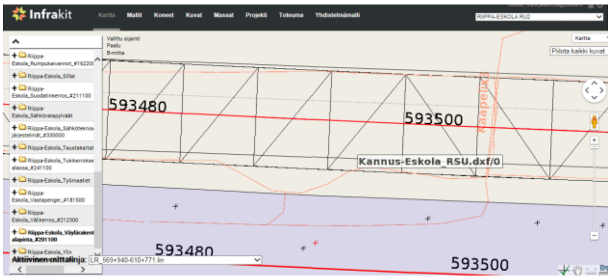

Figure 8. Model of track protection gauge in the Infrakit user interface. This real-time function was developed in a machine control system (Novatron Oy) that warns the operator when the machine approaches the area. The implementation and final tests were carried out in the Kokkola-Ylivieska project.

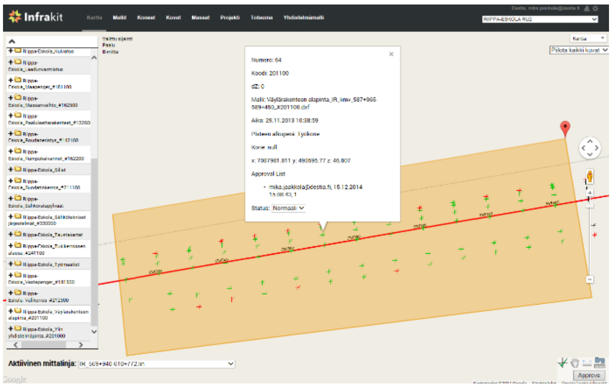

Figure 9. An Example - Supervisor 's tool for validating point quality in Infrakit cloud service. The inspected area can be delimited and accepted, causing the color of the actual points to turn green.

3.2 Railway Design and Construction Project Pasila Riihimäki, 1th phase (2016-2022)

The Pasila–Riihimäki design and construction project was the second major infrastructure design and construction project in Finland, in which the wider implementation and utilization of the Open InfraBIM was developed (Figs 10, 11 and 12). The success of the implementation was evaluated by an external consultant Netlipse.

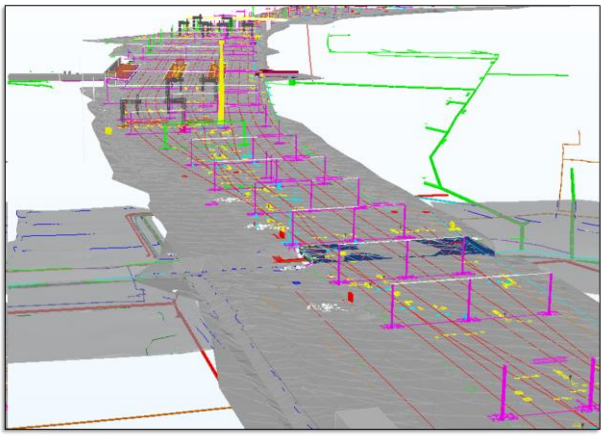

Figure 10. Initial data model of Pasila-Riihimäki project (Trimble Connect cloud service). The railway yard included lots of different structures. BIM models were seen necessary to handle the information.

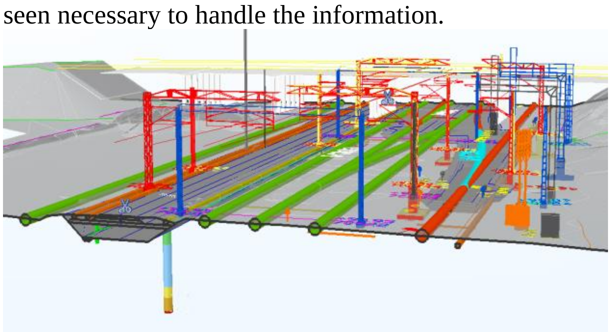

Figure 11. An Infra BIM example (Trimble Connect) – A Combination model of Pasila-Riihimäki project.

According to the external evaluation report of the construction project (Netlipse 2018) [14], the team has been in the project relatively thin and the members have felt themselves to have meaningful roles and responsibility for making decisions within their areas of competence. Issues referred to the Project Director (PD) for decision making have been dealt with quickly. The team appeared very confident in the PD's leadership and experience to ensure success. Motivation to deliver a quality product has been high.

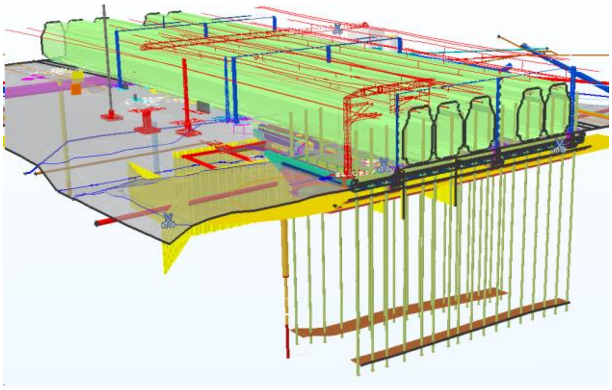

Figure 12. An Example - Utilization of InfraBIM in design (visualization, clash detection) and construction (Trimble Connect).

The decision to fully utilize the opportunities presented by BIM 3D modelling for design, construction and maintenance by the PD and team has been highly successful. The project has achieved significant cost savings (estimated at approximately Euro 10 million), efficiencies and quality improvement through this approach.

Cost management and control came out very strongly in most interviews with the PD proactively seeking to reduce anticipated final costs and deliver additional value through underspend. Procurement of contracts also very strongly focused on price.

The PD was an experienced leader and was involved in almost all aspects of the project delivery function. He has significant knowledge of the key issues and risks but has not documented much of this knowledge. In order for his successor and other team members to manage this transition, some form of lessons learned / knowledge capture was essential:

- a knowledge management plan (or lessons learned register) is strongly recommended due to the limited nature of formal project documentation and the strong reliance upon the PD and the team's personal knowledge and intervention.
- it is strongly recommended that the lessons learned through the adoption of BIM modelling should be captured and shared for the benefit of future schemes.

In the evaluation report it was also suggested that to ensure that original benefits are realized the FTIA could act in a more proactive client role to continue to measure benefits case during construction and then test those benefits are realized post completion. One of the key suggestions to FTIA was to continue BIM utilization development in future construction and maintenance project i.e. to exploit BIM opportunities nationally.

3.3 Highway Design and Construction project Vt4 Kirri-Tikkakoski (2019-2022)

In December 2021, the construction contract was up to eight months ahead of schedule [15]. According to the fairway agency, the rapid progress of the work was due to new ways of working in design, construction and quality control.

The design has been done entirely on a model basis, and no paper drawings have just been commissioned from the project. The time saving was about 20-22 weeks, i.e. almost half a year has been saved in design time. This has also been reflected in the construction schedule. A lot of new construction technology, quality management technology and design have been introduced and utilized in the project, which has enabled significant time savings. Automatic 3-D machine control systems were used for all the machinery, thus measuring sticks have not been installed on the site at all.

Project members can use combination model from Infrakit to monitor the current progress (see Fig 13). Infrakit can also use to real-time Model-based quality control using color to show tolerances (Fig 14) has been done as well as by using for example with drones (Fig 15). The quality information was produced in real time. The bridges were modeled, and all approvals were model-based using Trimble Connect, no papers were delivered to the client or for construction. Reinforcements were ordered from the factory according to IFC models, not with paper reinforcement lists. Bridge measurements were performed entirely according to IFC models, and no separate measurement data was created for bridge measurements.

Figure 13. Highway Design and Construction project Vt4 Kirri-Tikkakoski – a BIM model View in Infrakit Cloud Service (Destia Oy).

Theis large-scale road construction project has remained very well within its budget. According to FTIA, the initial cost estimate for the Kirri-Vehnia subscription was EUR 156 million. The actual construction costs were EUR 139 million. In addition to the Kirri-Tikkakoski project, 139 million were completed on an additionl Vehniä section, i.e. one interchange and six to seven kilometers of parallel road longer than was included in the original project.

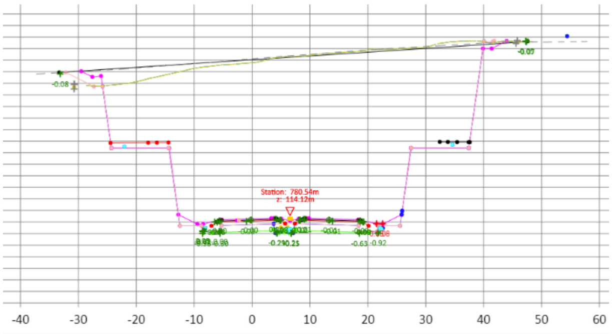

Figure 14. A sample of Infrakit Cross-section showing real-time quality deviations (green points inside tolerances, red points outside tolerances).

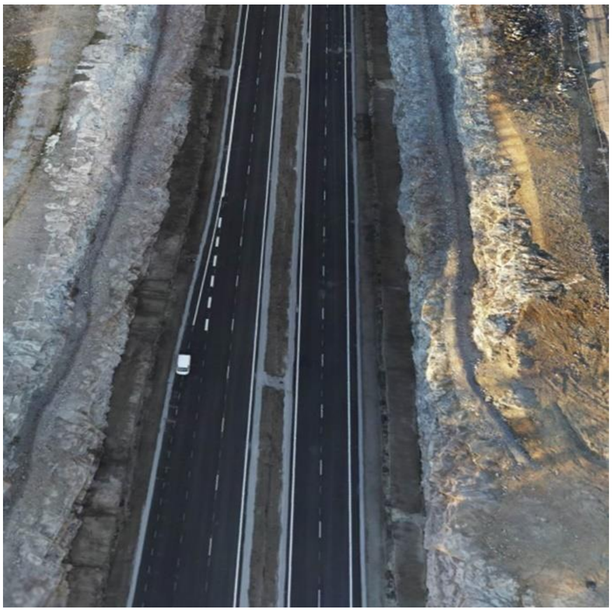

Figure 15. Example – a drone image used for model-based quality control (Destia Oy).

4 Conclusion

This study was carried out at the request of the industry in order to find out the benefits of Open InfraBIM in design and construction projects in Finland. It was especially hoped that the research would provide support for the introduction of the Finnish Open InfraBIM concept internationally.

In the earlier first project (2012-2018) already most of the employees interviewed had been in contact with the Finnish Open InfraBIM. In design, the greatest benefits were achieved from more illustrative design, coordination of different types of technology and reduction of errors. In construction, faster works, material savings and quality improvements were reported. Turnover time was evaluated to been clearly faster in construction. Significant savings from the use of BIM were achieved.

In the second project (2016-2020) the report stated that the project has achieved significant cost savings of Euro 10 million, i.e. about 7% of the total project cost, efficiencies and quality improvements.

In the later third project (2019-2022), the realized reduction in construction time was about eight months in the end of 2021. The rapid progress of the work was due to new ways of working in design, construction and quality control. The time saving in design was about 20-22 weeks. All the machines were equipped with automatic machine control systems. Real-time quality control was seen to been preventing potential faults at an early stage during construction.

The implementation of the Open InfraBIM concept has been successful in Finland. Clear economic and technical benefits were observed and measured in all of the considered major design and construction projects carried out in 2012-2022. The most remarkable benefits were faster construction with reduction of construction time, cost savings up to 7% of total design and construction costs, and better completed quality of infra structures. Most benefits were found from the latest project Kirri-Tikkakoski with remarkable time savings. The benefits of BIM based machine control and real-time quality control were emphasized in that project. This project has also used the most advanced and widest InfraBIM concept with early integration with all relevant stakeholders. The technology had already evolved considerably further, and people (an experienced team) had learned to build model-based.

The continuous development of Open InfraBIM seems evidently to been reflected in the increase of benefits in design and construction operations and processes. The progressiveness and competitiveness of the Finnish BIM concept in similar systems in other countries is difficult to assess on the basis of this study. Further development, wider information sharing and utilization of the Open InfraBIM in Finland and globally are suggested.

References

[1] Costin, A. & Alireza, A. & Hanhin, H. & Stuart, S. C. (2018) Building Information Modeling (BIM) for Transportation Infrastructure – Literature Review, Applications, Challenges, and Recommendations. Automation in Construction 94 (2018), pp. 257-281.

[2] Dodge Data & analytics (2017) Smart Market Report Top Business value of BIM for infrastructure.

[3] Nhat Nam Bui (2021) Implementation of Building Information Modeling in Infrastructure Construction. Doctoral Dissertations at the University of Agder 329.

[4] Bergs, R. A. & Winkels, H. J. (2016) InfraBIM in den Niederlanden. https://henry.baw.de/bitstream/20.500.11970/102344/1/04_Bergs-Winkels_InfraBIM.pdf

[5] Boykov, V. N. & Skvorsov, A. V. & Gurev, V.A. (2020) InfraBIM Open paradigm as the driver of information of the road sector in Russia. IOP Conf. Ser.: Mater. Sci. Eng. **832** 012045.

[6] Giovine, A. (2019) Thesis: InfraBIM e construction management: valutazione di interoperabilita OPEN BIM. https://webthesis.biblio.polito.it/11128/1/tesi.pdf

[7] Halttula, H. (2020) Enhancing Data Utilization in the Construction Project Lifecycle through early Involvement and Integration. University of Oulu, Graduate School, C Technica, C750, 112 p.

[8] Caterpillar (2016) Comparison report, Caterpillar jobsite information study, 22 p.

[9] Caterpillar (2006) Road construction – production study. 26 p.

[10] Kivimäki, T. & Heikkilä, R. (2015) Infra BIM based Real-time Quality Control of Infrastructure Construction Projects. ISARC’2015, The 32nd International Symposium on Automation and Robotics in Construction and Mining, 15-18 June, 2015, Oulu, Finland.

[11] Final report of Inframodel3 pilot project for data modelling-based planning and construction process. Finnish Transport Agency, Planning Department. Helsinki 2015. Research reports of the Finnish Transport Agency 17/2015. 45 pages and 2 appendices. ISSN-L1798-6656, ISSN 1798-6664, ISBN 978-952-317-077-3.

[12] Liikennevirasto (2015) Tietomallipohjaisen suunnittelu- ja rakentamisprosessin Inframodel 3 pilotti, loppuraportti.

[13] BuildingSMART Finland (2022) Infrastructure, YIV2019 guidelines, Inframodel, InfraBIM classification system, InfraBIM Glossary of Terms, https://buildingsmart.fi/en/infrabim-en/

[14] Netlipse (2018) Preliminary Feedback Session. IPAT Pasila Riihimäki 1th phase. Evaluation report.

[15] YLE (2021) – the News Agency in Finland. Mitä ihmettä? Moottoritie valmistuu kuukausia etuajassa ja pysyy budjetissa