Automated Dynamic Management of Road Construction Sites

R. Heikkilä[a], E. Viljamaa[b], A. Kaaranka[a], T. Makkonen[a] and I. Peltomaa[b]

[a]Construction Technology Research Center, University of Oulu, Finland
[b]VTT Technical Research Centre of Finland, Finland

E-mail: rauno.heikkila@oulu.fi, esa.viljamaa@vtt.fi, annemari.kaaranka@oulu.fi, tomi.makkonen@oulu.fi, irina.peltomaa@vtt.fi

Abstract - Automated dynamic management of road construction sites has been studied within the DigiINFRA research project in Finland. A review of currently available commercial solution, including most popular commercial softwares and systems in global markets (Topcon Sitelink3D, Trimble applications, Novatron Xsite, Leica iCONTelematics, Infrakit), is drawn. Test results of the last campus site experiments using the special DSCC (Dynamic Site Control Center) prototype system developed in the DigiINFRA research project are presented and analysed. Some site observations of the use of the commercial site control systems are presented as well. The special demands set by the dynamic site management to the development of general information modelling or national infra BIM specifications and the related open information transfer standards are introduced and evaluated.

Keywords - Automation, Road Construction, Dynamic Management, Dynamic Control

1 Introduction

Road and railway construction is mainly earth moving work, to which automation and robotics apply very well. The automation of earth moving is primarily information model based automation. Large utilization of information modelling and automation in infra sector is possible as long as the common ground rules and specifications have been created for the industry. This is one of the main aims of the active Infra FINBIM [1] research in Finland.

The design information needed for construction of roads and railways is typically both place-based and time-bound. Main challenge is to perceive the linking between different type of information (place, time, task, planned schedule, resources, planned geometry of structures, material, etc.). All the design information, such as schedules or the surface models of structures, form a static information of the project, which has to be connected real-time with the information captured from site. The dynamic information gathered from site includes information about the places of machines and workmen, different statuses, work tasks, working conditions and the progression of the tasks. From these information different performance quantities can be calculated describing the function of separate work tasks as well as the whole construction process on site. Different information can be illustrated and shared case by case using suitable specified user-interfaces and licenses according to the profiles of workmen.

2 Dynamic Management of Road Construction Site – Experiments with the DSCC Prototype System

In this study, dynamic management was determined to mean flexible, fast and efficient reaction to control of different working tasks on site. In addition, dynamic management was determined to be such a system that is information modeling (BIM) based, internet browser-based, independent of different terminals, and utilizes wireless and mobile information transfer. The most important part sectors of the dynamic management in road construction are the tracking and control of schedule, costs, materials, work staff, machinery, sub contractors and site traffic.

University of Oulu and VTT Technical Research Centre of Finland studied the dynamic control of road construction site in the research project "Dynamic management of digital product process in a dynamic co-operation network (DigiINFRA)". In the research, the functions of road construction management were cleared and prioritized by interviewing site foremen. In addition a special base for application integration and different new types of information models were developed. [2][3][4][5] For the experimenting, the Dynamic Site Control System (DSCC) was implemented [6]. Figure 1 presents the information sources and different visualization alternatives of DSCC prototype system.

DSCC system was tested on the common campus test site of University of Oulu and VTT. In the tests, an excavator equipped by the VisionLink 3D machine control system of Novatron Oy and three cars representing dump trucks were used. DSCC offers different specified web-based process views, which are based on the integrated design and as-built information. For example, this kind of process views can be map or status views as well as different design or as-built views of project tasks. In Figure 2 there is a picture of construction site's control center build in a room of University of Oulu's premises in order to control the campus tests. In the control center the DSCC user-interfaces were used for the dynamic control of the earth-moving works on the campus test site. Figure 3 gives an example of DSCC system's real-time schedule control view [6]. As the reference systems in the experiment, the Kuura system of Hohtolabs Oy [7] and Xsite system of Novatron Oy [8] were used.

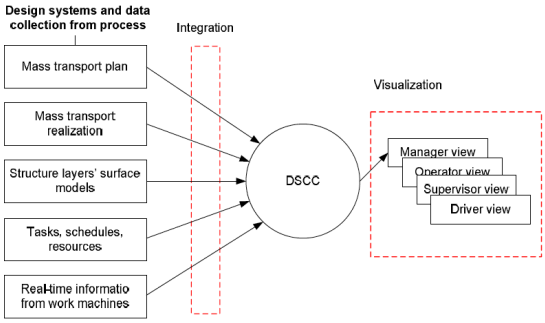

Figure 1. Information sources and information visualization in DSCC prototype system. (VTT).

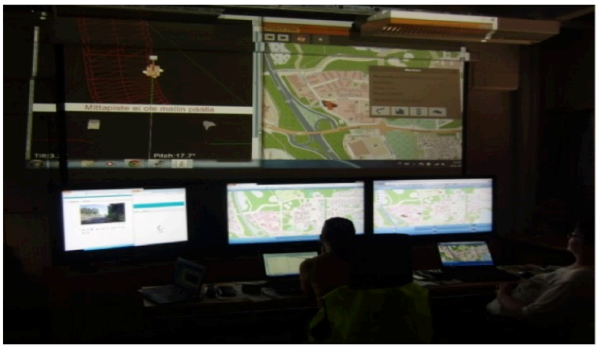

Figure 2. Campus site tests control center.

In the campus tests, the design and modelling of road part was done by Tekla Civil software [9]. The alignment information and material quantities were transferred and utilized in the DSCC tests. The resource and schedule planning was done using PlaNet software [10]. The as-built information in the tests was produced by a special web-based material transfer application as well as using the VisionLink 3D machine control system. The design and as-built information were integrated and saved to the semantic data base used. In the experiments, the dynamic track and control was tested six work days. The passage of time was simulated, but other functions were realized on site.

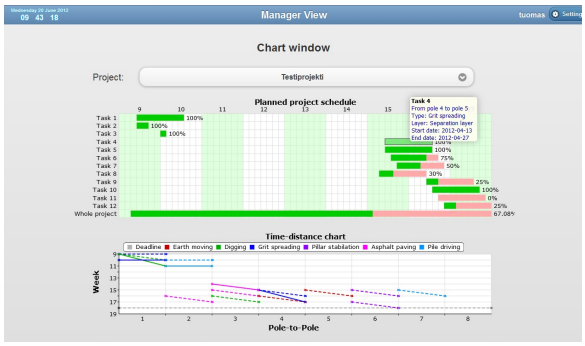

Figure 3. DSCC system's real-time schedule control view.

3 Examining Commercial Software and Systems

The Infrakit system of Infrakit Oy is a web-based information management system for infra construction sites. Design data and different production files can be shared to site personnel and work machines. Also the quality of uploaded files can be checked automatically. Latest production models and alignment lines can bee seen by computers and tablets. The Infrakit tablet application shows the models with the digital terrain model and alignment lines. Locations of work machines are shown on the map as well. Some of the commercial machine control systems have real-time information transfer with the Infrakit system. A special as-built data measurement application is included having the feature to automatically calculate the deviations between designed and measured coordinates. Also photos and PDF files can be saved to the Infrakit data bank.

Figure 4. Infrakit tablet system on-site use in a real road construction project in Finland. The site foreman is considering a cross-section of the 3D machine control model.

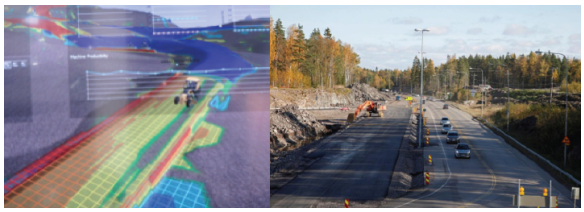

Figure 5. Topcon SiteLink3D system (left picture) for the control of road construction site (right picture).

Topcon corporation has introduced and publicated new SiteLink3D [11] systems, which integrates very broadly all of the different information models needed for construction operatives. The information exchange is made real-time. Moving machines are shown on maps and in 3D information models, the surfaces measured by 3D machine control systems are updated automatically to data bank and computer views as well. There is also an integration with Dynaroad [12] mass hauling and schedule optimization design software.

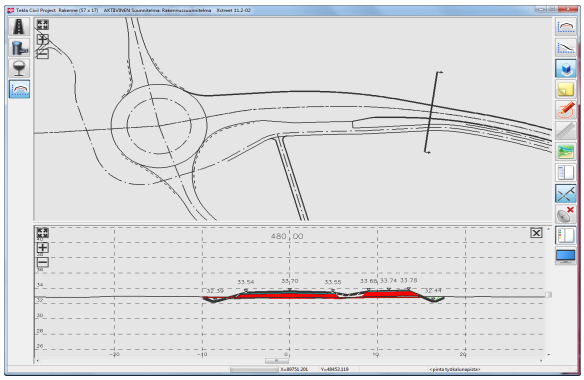

Figure 6. The user-interface of Tekla Civil for site purposes.

Figure 7. Information model based quality monitoring by Trimble VisionLink system. In the Trimble system the as-built surveys are done by CSC900 control system installed into compacting machine.

Tekla Civil (Trimble Corporation) has been complemented with a new Field Mode application for site use purposes by tablets. The application can upload all the information needed directly from Tekla Civil data bank. Different information models can be examine three-dimensionally. The information transfer is done using Trimble Connected Community cloud serve application. Trimble Vision Link is the system for dynamic site control purposes, by which the progression of work tasks can be followed as well as quality control or as-built measurement data collected. It is worth noting that in this solution the geometric surveys of final road structural layers are done using 3D machine control system of compacting machines.

Figure 8. The main available functions of the Xsite system provided by Novatron Oy are the sharing of production models and as-built information, document searching and uploading, fleet management, status reports for each work machine used and instant messaging possibilities.

The new Xsite system developed by Novatron Oy offers functionalities for the sharing of production and as-built models and the searching and uploading of positioned documents. Machine positions can be shown on maps, different activity reports of machines can be produced, there is available remote access to operators and a special instant messaging tool.

Leica iCONTelematics includes versatile applications for remote site management, data transfer in both directions from the field to office, fleet management and reporting by a special Track tool.

Figure 9. The View tool of Leica iCONTelematics.

4 Conclusion

At the same time when infra industry is developing common Infra BIM guidelines, the next change and shaking is already coming from the side of technology companies. Now it could be possible to start the utilization of dynamic site control systems. DigiINFRA research project studied more extensively the challenges and potentials of dynamic management, of which some parts were tested in the campus test site environment using the programmed prototype system. The further development of this system is a real challenge and offers valuable means and potentials for the near future. The dynamic information integration includes very many possibilities, of which the commercial systems presented are already introducing. The importance of the development of open information transfer formats is amplified. In large construction sites, typically many of the different commercial systems are to be used at the same time. Therefore, open information transfer formats and standards needs to be extended to the level enabling dynamic information transfer.

References

[1] InfraBIM. InfraBIM etusivu (In Finnish). Online: http://www.infrabim.fi/, Accessed: 19/02/2014.

[2] Viljamaa, E., Peltomaa, I., Hovila, J., Heikkilä, R., 2012. A general information integration method for improved infrastructure building processes. In ISARC2012, 29th International Symposium on Automation and Robotics in Construction.

[3] Peltomaa, I., Viljamaa, E., 2013. Ontology in the Core of Information Management - Information Management in Infrastructure Building, ICEIS2013, 15th International Conference on Enterprise Information Systems.

[4] Viljamaa E. and Peltomaa I. Intensified construction process control using information integration. Automation in Construction, 39:126–133, 2014.

[5] Heikkilä, R. & Tiitinen, P. (2013) Dynamic Management of Road Construction Operations on Site. ISARC'2013, The 30th International Symposium on Automation and Robotics in Construction and Mining, 11-15 August, 2013, Montreal, Canada, 7 p.

[6] Viljamaa, E., Peltomaa, I., Seppälä. T., 2013. Applying web and information integration technologies for intensified construction process control. In ISARC2013, 30th International Symposium on Automation and Robotics in Construction.

[7] Hohto Labs. Hohto Labs. Online: http://www.hohtolabs.com/en/main, Accessed 19/02/2014.

[8] Novatron. Novatron Machine Control Systems - Excavator Control Systems - Excavator Guidance Systems - GPS Machine Control - 3D Machine Control. Online: http://www.novatron.fi/en/, Accessed 19/02/2014.

[9] Tekla. Tekla Civil | Tekla. Online: http://www.tekla.com/products/tekla-civil, Accessed 19/02/2014.

[10] Artemis. PlaNet (In Finnish). Online: http://www.artemis.fi/planet/, Accessed 19/02/2014.

[11] Topcon. Sitelink3D | Topcon Positioning Systems, Inc.. Online: http://www.topconpositioning.com/products/software/network-applications/sitelink3d, Accessed

19/02/2014.

[12] Topcon. Topcon TotalCare :: DynaRoad. Online: http://www.topcontotalcare.com/en/software/site-management/dynaroad/, Accessed 19/02/2014.