Next Generation One-Man Construction and Smart Construction
Powered by ICT Construction

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Abstract:
Environments surrounding Japan’s construction sites are becoming increasingly stringent due to the following reasons: declining birth rate, aging, maintenance of existing social stock and a lack of technology transfer due to retirement of skilled technicians. Promoting i-Construction which makes the maximum use of ICT in construction manufacturing process, the Ministry of Land, Infrastructure, Transport and Tourism of Japan (MLIT) aims to improve labor productivity by 20%. In 2013 fiscal year, Japan’s ICT initiatives for earthworks began researching “3D Data Exchange Standard Complies with the LandXML1.2”, this being the standard format to achieve data exchange in research, design, construction and operational management. The latest information was released in 2016 with the MLIT implementing over 400 cases per year thereafter. However, the implementation of the operation faced issues including “generation of three-dimensional data”, “ICT (MC/MG) data exchange operation” and “acquisition of operational method”. This study highlights case studies of projects where the development of new software, designed to automate operations, was used to improve the efficiency of construction operations by over 300%.

Keywords: ICT Construction, automation, survey instruments linkup, tablet device, smart construction

1. INTRODUCTION
Before discussing the main issue, the uniqueness of Japan’s topographical nature must be explained. While the land area of Japan is the 62nd largest in the world, complex embankment, earth cut, slopes, and drainage facilities are required due to the continuity of mountainous regions. For these reasons, the cross sectional profile of the road at embankment, earth cut boundaries and sections where structural elements abutting land, could vary significantly.

Various operations are required to meet such topographical conditions which include the production of road centerline alignment and road structure data during the design phase, conversion of road centerline alignment and road structure data produced during the design phase into ICT construction data and the organizing of construction control values generated in ICT construction phase. These operations involve various issues as highlighted below.

1) Production of three-dimensional schematic design data
In order to produce “3D Data Exchange Standard Complies with the LandXML1.2”, three-dimensional schematic design data must be generated from the traditional two-dimensional data. When the cross sectional profile changes significantly there is a necessity to define the continuous topographical formation between each two-dimensional section. Due to the complex nature of operations, the data production and editing, acquisition of software operating skills and cross examination of two-dimensional drawings of three-dimensional schematic design data can be time consuming.
(2) Data conversion operations to enable ICT construction
The use of three-dimensional schematic design data to generate two sets of data
a) Construction machinery MC/MG (Machine Control/Machine Guidance) data
b) Data to organize construction control values - can be time consuming.

(3) Education of young engineers to establish skills to handle survey instruments
There is potential for implementing one-man construction using an automatic tracking survey instrument for data measurement operations. However, guiding engineers without sufficient survey experience to survey locations can still be time consuming especially when new instruments are being introduced. In addition, the management of survey data at construction office could also be time consuming.

2. METHOD
In order to address the above issues, this study has developed software to automate the following tasks
1) Data conversion for ICT construction of road structure
2) Data measurement
3) Data management of construction control values obtained from ICT construction.

2.1 Visual confirmation using three-dimensional viewer
As shown in Figure 2, a, cross sectional profiles can be connected automatically and data can be edited to connect each cross section. In addition, the real-time three-dimensional verification feature has also been implemented. As explained in the “Current Issues” section, two-dimensional drawings are currently being used for tender in Japan. In order to address this point, the software is equipped with a feature to automatically or semi-automatically analyze and extract three-dimensional schematic design data elements from two-dimensional plan, longitudinal section, and cross section drawings, easily generate three-dimensional schematic design data and cross-reference accuracy of coordinates, and superimpose three-dimensional data into plan drawings, as shown in the Figure 3. (Figure 4)

2.2 Efficiently generate multiple data
By generating and importing three-dimensional schematic design data produced in the design phase the software can simultaneously generate MC/MG (Machine Control/Machine Guidance) data required for construction machinery operation and data to manage construction control values.
2.3 Development of app with survey instruments linkup
A smartphone app (patented) with the ability to linkup with an automatic tracking survey instrument has been developed. The app generates and displays locations to measure construction control values in real-time and guides survey operators and inspectors via voice navigation (Figure 6). Using three-dimensional schematic design data and route data, survey positions, altitude variation, horizontal variation, and vertical variation are displayed. In addition, the app is equipped with a feature to use the measurement data to record construction control values onsite and upload the data to the cloud to manage construction control values (Figure 7).

3. RESULTS
3.1 Greatly reduce operation time to produce three-dimensional schematic design data and organize construction control values
With the ability to verify the cross-sectional profile editing process using real-time three-dimensional visualization, accurate three-dimensional schematic design data can be generated. Furthermore, because users can complete the operation simply by importing data uploaded to the cloud, the amount of time spent managing data has been reduced from several days to just one day.

3.2 Reduction of installation cost of dedicated construction machinery
In one case study project, prisms were installed to the backhoe shovel in order to enable the machine operator to directly verify the smartphone screen. With the ability to operate simply using survey instruments and tablet devices, 90% cost reduction was achieved in this particular project.
3.3 Improved efficiency of one-man construction
In addition to ICT construction, the system can help overcome issues, such as inexperienced engineers without sufficient surveying skills and lack of engineer availability, through support in staking operations and navigation to existing pile positions. Two examples are given below.
(1) Active participation of second-year female manager and over 300% improvement in site operations.
(2) Elimination of manual survey operators (cost reduction of 60 man hour in 180-day road construction project = over 1,000,000).

3.4 Application in other countries
The following features may be implemented to address issues in other countries:
(1) Visual confirmation function using three-dimensional viewer
In USA, the client supplies three-dimensional design data to the contractor. The ability to superimpose two-dimensional drawings and three-dimensional data can address any discrepancy between the client’s supplied data and the site conditions, as well as discrepancies between two-dimensional drawings and three-dimensional data. In Germany, the contractor produces working drawings based on rough design drawings supplied by the client. Therefore effectiveness similar to that of Japan may be expected.

(2) Development of app with survey instruments linkup
In USA, surveying of completed sections are undertaken at 2-week intervals but survey locations and frequencies are random and inconsistent. The app can help reduce inspection time of inexperienced engineers.

(3) General
Finland uses an Open BIM cloud product called Infrakit. Although the editing of data is not supported, the system can linkup with construction machineries. By synchronizing the system with features of this software productivity can be improved.

4. CONCLUSIONS
By utilizing “3D Data Exchange Standard Complies with the LandXML1.2”, a smooth data exchange can be made possible and the use of ICT enables a 20% increase of labor productivity. In order to achieve further improvement of labor productivity throughout the project life cycle additional interconnectivity with BIM supporting products must be developed.
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