Improvement of Productivity at Construction Sites

1. Outline of Studies and Activities

Event	Challenges	Details of the research	Reflection of research outcomes
✧1996 Basic Concept for the Development of Construction CALS, 1997 Construction CALS/EC Action Program (Promotion of digitization within the government) ✧2002 Ministry of Land, Infrastructure, Transport and Tourism CALS/EC Action Program ✧2005 Ministry of Land, Infrastructure, Transport and Tourism CALS/EC Action Program 2005	• Cost reduction, quality assurance, and efficiency improvement of project execution through computerization of information, exchange, sharing, and coordination of information on public works projects among organizations and project phases • Elimination of hazardous and arduous work in civil engineering construction	• Study of efficient construction management and supervision/inspection methods using measuring equipment and construction machinery • On-site trial and verification of total station (TS) for complete form control • [General Technological Development Project 2003-2005] Development of IT construction system using robots and other technologies	• Guideline for complete form control using TS that can be equipped with construction management information (trial version) and a supervision and inspection manual • Started trial implementation of information-based construction for directly controlled construction projects in FY 2008
✧July 2008 Strategies to promote information-based construction ✧March 2009 .CALS/EC Action Program 2008 (until 2010)	• While the distribution of electronic data is advancing, only paper-based documents are being digitized, increasing the labor required to create electronic deliverables. • Skilled operators of construction equipment are becoming scarce due to the aging of the workforce, etc.	• Study of complete form control method using 3D surveying instruments with satellite positioning technology • Study of expansion of work types for complete form control using TS • Study of standards for exchanging road center line formation and road crossing shape data	• Guideline for completed shape control using TS (earthwork edition) (pavement construction edition) and also supervision and inspection guideline (river earthwork edition) (road earthwork edition) (pavement construction edition) • In principle, the use of TS-based complete form control technology in construction under direct management of the national government started in FY 2013.
✧March 2013 Strategies to promote information-based construction	• Burden on contractors increased in creating data required for information-based construction. • Review of technical standards, bidding and contracting systems, and other rules that take advantage of the characteristics of information-based construction.	• Examination of efficient methods of creating data for information-based construction. • Study of new standards for 3D data for ICT earthworks • Survey on utilization of 3D data for using CIM	• Construction management data exchange standard for complete form control using TS (draft) Ver. 4.0 • Guideline for complete form control using unmanned aerial vehicles and laser scanners (earthwork edition) • 3D design data exchange standard based on LandXML 1.2 (draft) Ver. 1.0
✧2016 Positioned as the first year of productivity revolution and promoted i-Construction ✧2021 Release of DX measures in the infrastructure sector	• Entering an era of declining population, the number of workers who have supported growth so far is decreasing. • Productivity is drastically improved by utilizing ICT and other technologies in all construction production processes from surveying and measuring to design, construction, inspection, maintenance, management, and renewal. • Digitization of on-site construction data is necessary to consider streamlining and mechanization of construction.	• [General Technological Development Project 2017-2020] Improvement of construction productivity through the full use of ICT • [General Technological Development Project 2018-2020] Advancement of construction production systems using AI • [PRISM] Innovation in construction sites through the promotion of i-Construction • Keeping track of skilled workers and on-site transport operations and the digitalization of construction data	• New standards for design, construction, and inspection using 3D data required for i-Construction • CIM implementation guidelines and other BIM/CIM-related standards • Preparation of guidelines (drafts) for complete form control using 3D measurement technology

1) Background events, social changes, etc.

As we enter an era of declining population and an ever more serious aging of society with fewer children, the construction industry is facing a greater decline in the number of workers than other industries (Figure 1). While mechanization has improved productivity in some types of work, there is significant room for improvement in earthwork and concrete work, where productivity has changed little (Figure 2).

With this background, the Ministry of Land, Infrastructure, Transport and Tourism has positioned 2016 as the first year of the productivity revolution and launched the Productivity Revolution Project to achieve economic growth by improving productivity to outpace the decline in the number of workers. One of the major projects of the Productivity Revolution Project is i-Construction. This initiative aims to optimize the entire process of infrastructure development from survey and design to construction, inspection, and maintenance, thereby improving productivity at construction sites and making them more attractive.

In March 2016, the NILIM launched the i-Construction Promotion Headquarters, which is engaged in research, development, and dissemination related to improving productivity at construction sites through the use of ICT and 3D data.

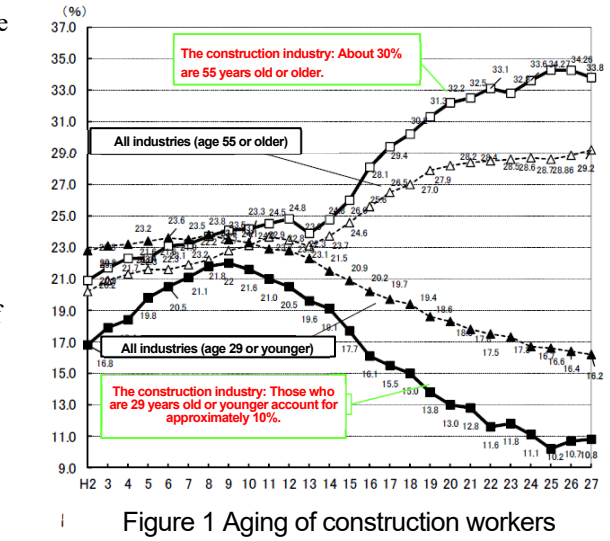
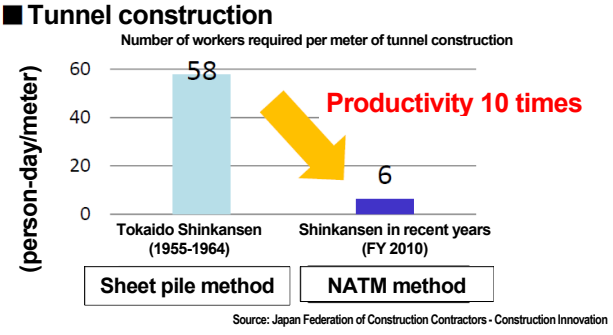


Figure 1 Aging of construction workers



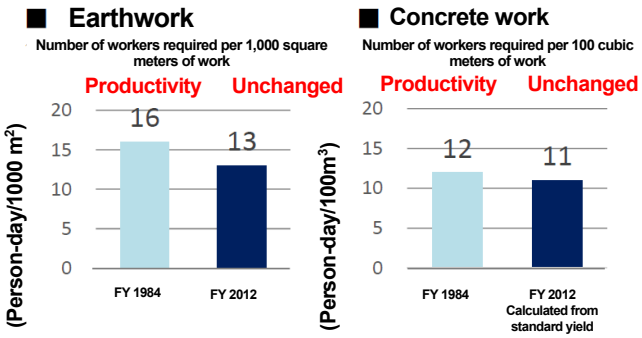


Figure 2 Trends in productivity of main work types conducted directly by the national government

2) Research and development tasks and outline of activities

(1) Information-based construction (ICT construction)

The NILIM has been working on research and development issues, such as the study of efficient construction management and supervision methods using measuring instruments and construction equipment, field trials, and verification of complete forms using total stations (TS), as well as the development of IT construction systems using robots and other equipment. These activities have been intended to address social issues, such as cost reduction, quality assurance, and efficiency in the project execution of public works projects through the computerization of information and the elimination of hazardous and arduous work in civil engineering construction. Since then, the NILIM has been working on the creation of rules and standards for the use of ICT for earthworks since the full use of ICT (ICT earthworks) was positioned as a top-runner measure for i-Construction. The NILIM has also been conducting research to expand the types of ICT construction work and to formulate and revise standards based on the demands of the private sector and other sectors.

(2) Construction CALS/EC, BIM/CIM

The NILIM has conducted research for information exchange, sharing, storage, and data reuse using electronic data, such as computerization of survey and design work and construction deliverables and CAD of drawings. With the aim of improving efficiency in design, construction, and maintenance, it has also been studying and developing methods for smooth distribution of 3D CAD design and construction data, as well as technologies for its utilization in maintenance and management. These activities have been intended to promote the digitization of the various types of information generated at each stage of the construction production process and to promote a public works support integrated information system

(construction CALS/EC) that creates an environment for efficient exchange, sharing, and coordination of information among all parties involved.

The NILIM has since developed technologies and considered standards for the smooth distribution and utilization of 3D models throughout the construction production process as Construction Information Modeling/Management (CIM), which incorporates elements of Building Information Modeling (BIM), which is now being introduced in the construction field.

(3) Research on digitization of skilled workers' movements

The NILIM is conducting research on concrete frame work, a major work type in public civil engineering projects, to analyze physical labor productivity by measuring and digitizing the work and work hours of skilled workers to improve efficiency and mechanize the construction work. The purpose of this research is to solve issues, such as securing workers, improving the working conditions and working environment of skilled workers, and developing, disseminating, and passing on efficient construction methods.

2. Main Research Results

(1) Information-based construction (ICT construction)

♦ Study on information-based construction (2001-2007)

- The NILIM developed a total station-based complete form control technology and verified its effectiveness and issues through field trials. Based on this, by FY 2007, the NILIM developed a construction management guideline (draft), a supervision and inspection guideline (draft), and technical standards (functional requirements for hardware and software, data format, etc.) to improve the environment for operation in the field. These have since been introduced into construction projects conducted directly by the national government throughout the country.
- These guidelines and standards have enabled the use of a total station (hereinafter referred to as "TS") equipped with construction management information instead of the conventional tape measures and levels as the measuring device. It thereby made it possible to measure the complete form with 3D coordinate values and use them for construction management and supervisory inspections.
- This enabled the operator to grasp the difference between the measured and designed shapes of the complete form on the TS screen at construction sites. It also made it possible to automatically create the complete form ledges and drawings on computers.
- In response to the Strategy for Promoting Information-Based Construction formulated by the Ministry of Land, Infrastructure, Transport and Tourism in July 2008, a draft of a procedure for complete form control using 3D design data and a procedure for supervision and inspection was prepared by FY 2011 so that ICT technology could be directly used for complete form control and supervision and inspection at actual construction sites.

♦ Study on i-Construction (ICT construction) (2016-)

- Full-fledged ICT-based construction work starts as part of the promotion of i-Construction measures that began in FY 2016. Construction know-how and needs have been accumulated through ICT-based construction. The development of various measurement technologies has been accelerated mainly by construction equipment manufacturers and measuring instrument manufacturers. Along with these trends, the NILIM has been conducting measurement verification and data analysis at actual sites and test fields. It has also gradually expanded the applicable work types while taking into account the know-how for productivity improvement that has been gained through interviews with clients and

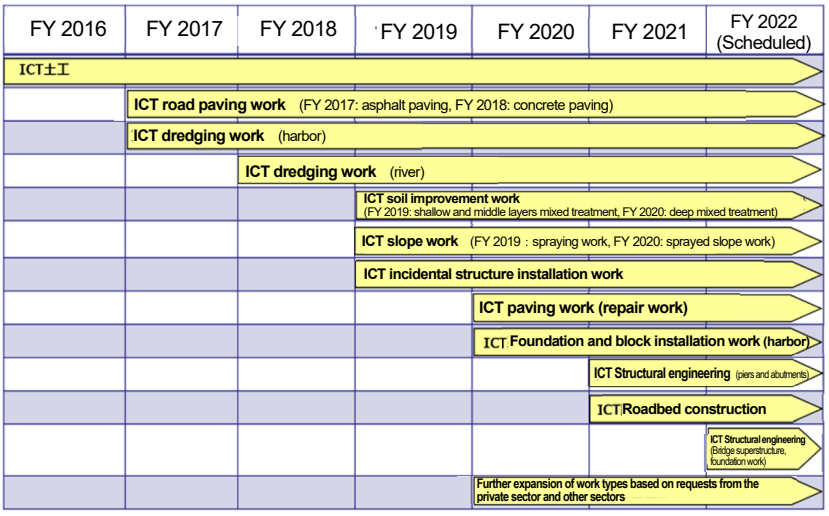


Figure 3 History of the expansion of ICT-based construction work types

contractors. It has also created and reflected a variety of standards, including complete form control standards, totaling 27 standards for 10 construction types. (Figures 3 and 4, Table 1)

- In preparing the standards, specific methods for each process of 3D ground survey, 3D design data generation, ICT construction, 3D complete form surveying, and complete form control/inspection are organized in the form of guidelines. The purpose of doing this is to enable the use of point group data acquired by laser scanners, which are ICT-based measurement technologies, the construction history of ICT construction equipment (cutting edge positions), and data acquired over an area for complete form control and construction management.

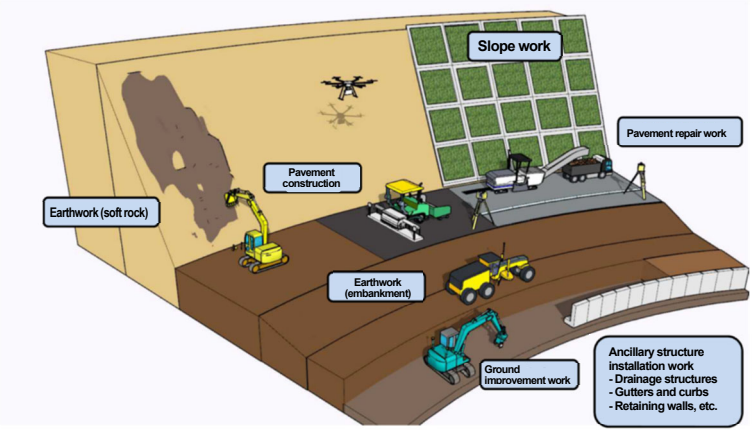


Image of the expansion of construction types that realize full use of ICT

Figure 4 Image of the expansion of construction types that realize full use of ICT (Example of road construction)

- The number of applicable standards has increased, and there are calls for improved convenience from constructors and others who are utilizing the standards for the first time. The guidelines have been compiled into a single document, "Guideline for Complete Form Control Using 3D Measurement Technology (draft)," so that the required work types, ICT technologies to be used, and applicable standard values can be easily indexed. The NILIM is improving the standards like this based on examples of actual applicable construction projects. (Table 1)

Table 1 Complete form control standards concerning ICT construction

Name of standard procedure	Latest version
Guideline for complete form control using 3D measurement technology (draft)*	2021. 3
Guideline for complete form control using 3D measurement technology (draft) (piers and abutment edition) (trial)	2021. 3
Trial guideline for management of compaction of roadbeds using acceleration response method (draft)	2021. 3
Guideline for calculating earthwork volume using ground photogrammetry (video type) (draft)	2020. 3
Guideline for calculating earthwork volume using construction history data (draft)	2019. 3
Guideline for calculating earthwork volume using stereophotogrammetry (ground moving object) (draft)	2020. 3
Guideline for embankment compaction control using TS and GNSS	2020. 3

※ Summary of 17 standards for complete form control using various 3D data measurement technologies developed since 2016

- Coupled with the progress in the spread of ICT-based construction work, the development of ICT-based measurement technology and the accumulation of construction know-how are rapidly advancing, mainly at the private-sector, thanks to the efforts of development manufacturers in the private sector. As a result, new measurement devices are being introduced to the market every year, including mobile-mounted laser scanners, UAVs equipped with laser

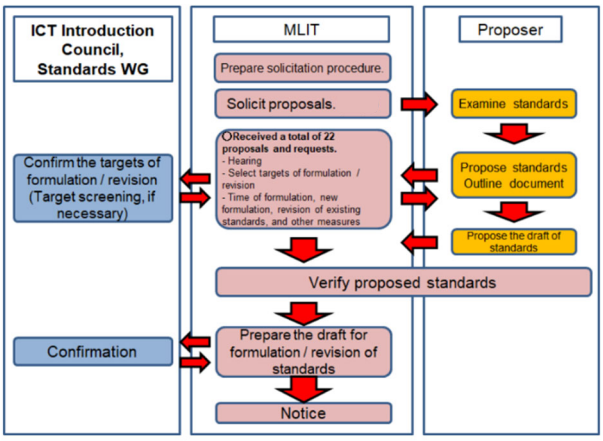


Figure 5 Basic framework for formulation and revision of standards based on requests from the private sector

scanners, and non-prismatic TS. Construction methods that utilize these productivity-improving devices should be reflected in public construction standards in a timely and appropriate manner to incorporate the latest measurement technology and construction know-how. Therefore, starting in FY 2019, the NILIM has been verifying the required accuracy assurance while receiving suggestions from development manufacturers, constructors, and researchers as a new formulation and revision of standards based on requests from the private sector regarding the use of ICT. This has led to the creation of new standards and the revision of existing standards. (Figure 5)

In these efforts, the NILIM is conducting verification and follow-up at actual construction sites as needed, as well as continuously providing technical support to the national government, local governments, and constructors.

(2) CALS/EC, BIM/CIM

♦ Study of 3D CAD data (2007-2013)

- It has become necessary to develop an environment for exchanging and collaborating with 3D data that will lead to increased efficiency and sophistication of construction operations. For this reason, the NILIM has studied and developed methods for the smooth distribution of 3D CAD design and construction data. This led to the creation of a data model for distributing 3D design data related to road and river projects, and to the creation of the 3D design data exchange standard (draft) as a data model for distributing 3D design data related to road and river projects. (Figure 6)

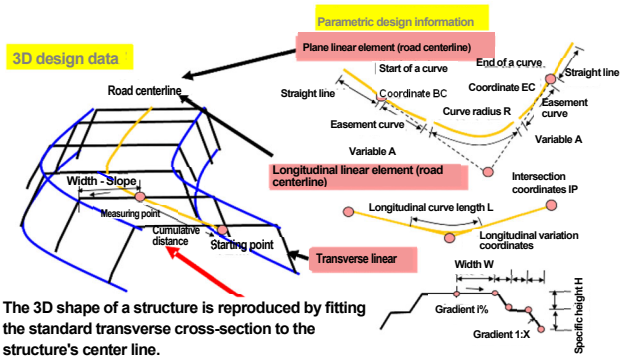


Figure 6 Overview of 3D design data model

- Furthermore, the 3D design data exchange standard (draft) based on LandXML, which is described in the LandXML format supported by many Japanese and foreign software, was created and published and is being used as a data standard.

♦ Survey for the introduction and use of BIM/CIM (2014-)

- Research on technology development and standardization for the smooth distribution and utilization of 3D models throughout the construction production process has produced results. The results have then been reflected in BIM/CIM-related standards and guidelines in various fields, including the creation of 3D models, verification and inspection of design deliverables, quantity calculation using models, electronic delivery of models, and functional requirements for applications. (Figure 7)
- Since the start of the trial in FY 2012, the number of operations and construction projects utilizing BIM/CIM has steadily increased. The Ministry of Land, Infrastructure, Transport and Tourism has set a goal of applying BIM/CIM principles to all public works projects, except small-scale projects, by FY 2023 and is gradually expanding the application of BIM/CIM.

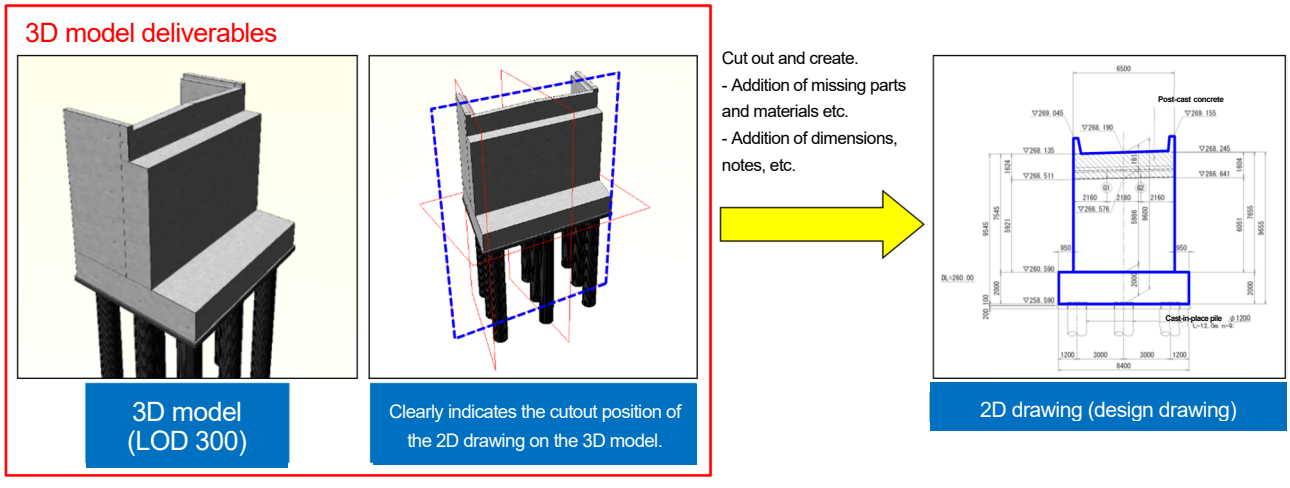


Figure 7 Example of preparation of contract documents based on the guidelines for preparation of 3D model deliverables (draft)

3. List of related reports and technical documents

Technical Note of NILIM No. 483 Material concerning as-built management with uses total station
http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0483.htm
Technical Note of NILIM No. 371 Road Alignment Data Exchange Standard – Basic Road Alignment Ver. 1.0
http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0371.htm
Technical Note of NILIM No. 505 Investigation about the as-built management using a total station in earthworks
http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0505.htm
Project Research Report of NILIM No. 43 Research on Advancement of Design, Construction, and Maintenance Management Using 3D Data
http://www.nilim.go.jp/lab/bcg/siryou/kpr/prn0043.htm
Technical Note of NILIM No. 903 3D Data Exchange Standard Complies with the LandXML1.2 – ver.1.0
http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0903.htm

4. Future Outlook

Although the number of construction projects utilizing ICT earthwork and BIM/CIM-based operations and construction projects has been increasing every year, they have not yet achieved full diffusion. Particularly for small and medium-sized construction companies in rural areas, the initial investment cost and difficulty in acquiring the technology make it difficult to spread the technology. In the future, technology related to i-Construction will be built not only for the MLIT officials but also for local government officials and private companies, including small and medium-sized construction companies. At the same time, it is necessary to develop an environment in which 3D data, such as BIM/CIM, can be easily utilized.

In addition, the COVID-19 pandemic has triggered an urgent need to accelerate the construction of an economic structure that is resilient in the face of infectious disease risks, including a shift to noncontact, remote working methods at public construction sites. The Ministry of Land, Infrastructure, Transport and Tourism launched a DX Promotion Headquarters for the infrastructure sector in July 2020. This will transform social capital and public services based on the needs of the public by responding to rapid changes in socioeconomic conditions and utilizing data and digital technology in the infrastructure sector. At the same time, the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) will promote cross-ministry initiatives to change the work itself, organizations, processes, culture, climate, and work style of the construction industry and the MLIT to promote public understanding of infrastructure and to realize safe, secure, and affluent lifestyles.

As part of this initiative, the NILIM has been storing and managing 3D digital data, such as BIM/CIM collected and created at each stage of projects conducted directly by the national government since FY 2020. In addition, the DX Data Center is being built with the minimum display functions required to utilize BIM/CIM and a Web conferencing function that allows the shared display of 3D data. Furthermore, as a base for research and development of technologies to support the promotion of infrastructure DX, the construction DX experimental field is being developed to develop and verify technologies for autonomous construction of construction equipment using 5G communications and the measurement and inspection of complete form of a structure using 3D data.

Once the DX Data Center starts operations and can be accessed externally via the Internet, data can be easily exchanged and shared between clients and contractors. The users can then use it to check the design on a 3D display, check the site conditions, and witness and inspect the site through remote meetings. In addition, if the development of construction technology using remote construction equipment and complete form verification/inspection technology using the construction DX experimental field becomes practical, it will help reduce labor and improve the efficiency of work at construction sites. We believe that these efforts are expected to help both clients and contractors improve productivity and achieve changes in the way they work.