User-Centered Design of K-D2PLANNER® Crane Construction Planning Support Software

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Abstract

In April 2023, the Ministry of Land, Infrastructure, Transport and Tourism announced its guidelines for the application of Building Information Modeling (BIM). In response, general contractors and others are accelerating their efforts to connect all the processes of design, construction, and maintenance to improve efficiency. Based on user feedback, Kobelco Construction Machinery has developed K-D2PLANNER®, software to support crane- construction planning, focusing on connecting the design and construction processes and aiming to solve the challenges of that process. The expected results include preventing interference between cranes and structures during the construction process, confirming the required crane capacity and ground pressure, and commonizing construction procedures to prevent the need for reworking at the site, as well as suppressing construction delays and the incurrence of additional cost. It is also presumed that streamlining model creation can reduce the costs of construction planning, and selecting the optimal crane can reduce execution costs, contributing to increased productivity.

Introduction

In 2019, the Ministry of Land, Infrastructure, Transport and Tourism established the BIM/CIM Promotion Committee to promote the use of BIM (building information modeling) in construction. The agency has also released guidelines for the use of BIM in all mid-scale and larger public-sector projects, effective April 2023. Although BIM is seeing increasing use in the construction sector, it remains underutilized in the crane construction planning process for steel structures. General contractors and others have established specialized departments to promote the use of BIM, connecting all processes of design, construction, and maintenance, and are accelerating efforts to make these processes more efficient.

Kobelco Construction Machinery developed the crane construction planning support software K-D2PLANNER® Note 1) with a focus on construction planning for crane-built steel structures. This software connects the design and construction processes and helps manage and solve challenges throughout the construction planning process. This paper introduces the functions of this software and describes how it supports construction planning.

Note 1) K-D2PLANNER® is a trademark of Kobelco Construction Machinery.

1. Challenges in crane construction[1)]

Among general architectural design firms, the rate of BIM application is about 80% in the design process and about 50% in the construction process. However, the use of BIM in construction planning, connecting the design and construction processes, has not progressed. The following are detailed challenges in construction planning for crane-built steel structures that can be addressed using BIM.

1.1 Site reworking

Certain issues could arise during construction that necessitate a major procedural revision and scheduling delay alongside site reworking. For instance, it could be discovered during site work that the crane boom or superstructure will interfere with part of the steel structure already built, necessitating temporary removal of structural members.

As another example, if the bearing capacity of the soil under a crane is inadequate, construction must stop for the installation of steel plates or other reinforcement. These reworking processes delay construction and result in additional costs.

1.2 Construction planning efficiency

Document preparation is a particularly time-consuming element of the construction planning process, such as in the creation of execution drawings as well as construction work plans as required by Article 88 of the Japanese Industrial Safety and Health Act.

Construction work plans require crane construction plans. To compile such documentation, experienced, knowledgeable professionals must spend considerable time referencing cross-sectional views and capacity figures to provide crane specifications and capacities.

On-site construction review meetings serve as a forum to discuss construction procedures and important agenda items. However, a great deal of explanation is required when only two-dimensional drawings are available to supplement the conversation, which can ultimately still result in misunderstandings.

1.3 Challenges to implementing BIM in construction planning

Using BIM in the construction planning process can reduce the reworking needs described previously. However, while architectural CAD is specifically intended to improve the design process of steel structures, it is not necessarily easy to use for crane construction planning. To use architectural CAD in the construction planning process, the planner must have experience and expertise not only in architectural CAD, construction planning, and construction, but also in crane operation and application (e.g., crane specifications and capacities).

Cultivating the requisite training and development in all areas necessary to use BIM in the construction planning process demands extensive time.

2. Overview of K-D2PLANNER®

K-D2PLANNER®, an add-in for the 3D architectural CAD program Autodesk Revit (trademark Autodesk), supports crane construction planning. The program's BIM models include 3D crane data, crane specifications and capacities, and functions to improve the efficiency of construction planning using cranes.

The sections below describe the software's main features and functions.

2.1 Intuitive operation

3D construction plans are used in the construction planning process for buildings.

They contain information related to the building structure, heavy machinery such as cranes, requisite crane capacities, building material weights, and more.

When using Revit to create 3D crane construction plans, it is usually necessary to change each individual parameter of the crane BIM model in **Fig. 1** and adjust the crane's posture based on the material being lifted. The suitability of the posture must be verified each time, which is a complex task.

When using K-D2PLANNER® in Revit, simply clicking the material to be lifted automatically

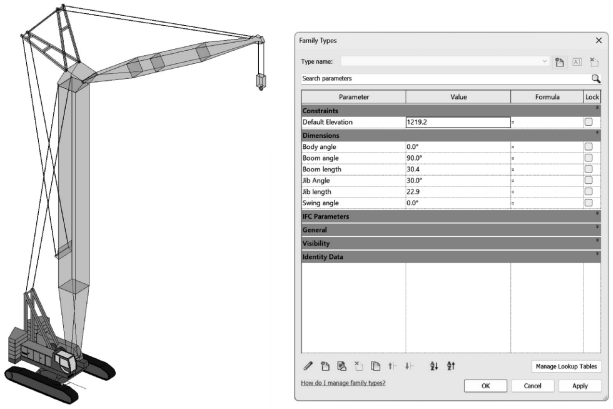

Fig. 1 Crane BIM model

changes the crane posture. The hook position is then determined with the wire rope sling at the recommended angle of 60° based on the shape of the material. The program indicates the distance from the top of the material to the hook as the interference area (**Fig. 2**).

This function makes it possible to visually confirm whether materials will contact structures during lifting operations (**Fig. 3**).

The interference area can also be expressed as a cylinder whose radius is the distance from the material's center point to its furthest edge in plan view (**Fig. 4**). This representation makes it possible to determine whether the material will contact another object if it rotates while suspended.

The working radius, maximum working radius, and minimum working radius (circles and cylinder in **Fig. 5**) can be displayed for a given crane posture. The tail swing radius (circle and cylinder in **Fig. 6**) can also be displayed, making it possible to check for interference when the crane enters a structure and is used in construction operations.

Further, the user interface has icons for the different functions and key numerical values accompanied by a representative image of a crane. In this way, users can operate the architectural CAD program intuitively even if they are unfamiliar with the names of crane parts (**Fig. 7**).

2.2 Simulation

To ensure safe crane operations, construction planners check the load factor and ground pressure of the cranes and determine whether there could be interference between cranes and structures. The load factor indicates how much load the crane can handle. Lifting a load that exceeds the load factor could result in an accident, such as the crane tipping. Ground pressure indicates the pressure exerted by the crane on the ground. Excessive ground pressure could cause ground subsidence, followed by the

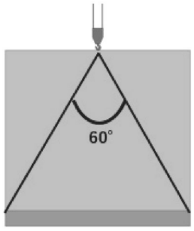

Fig. 2 Area of wire

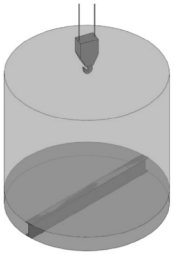

Fig. 4 Cylinder expression

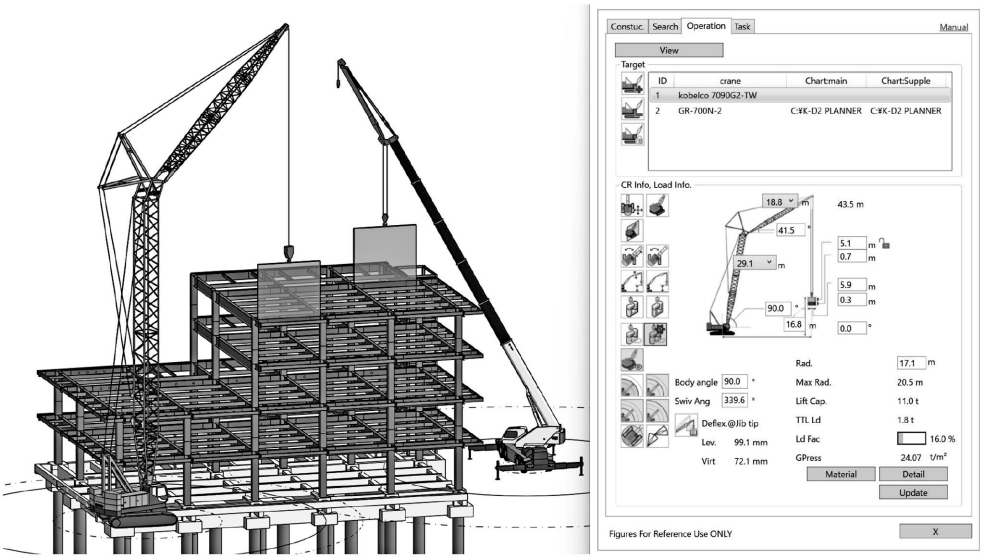

Fig. 3 Lifting image on K-D2PLANNER®

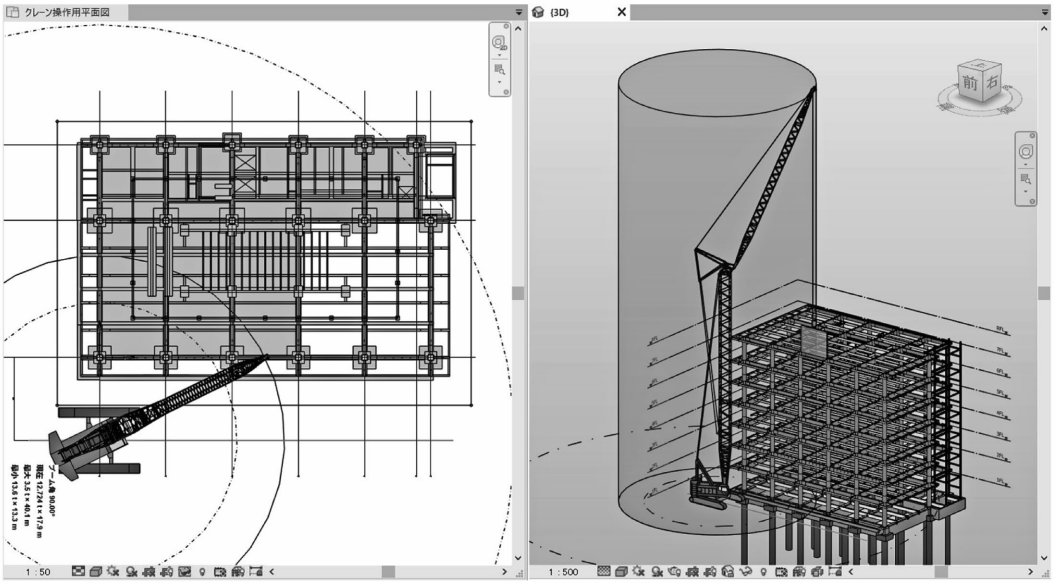

Fig. 5 Maximum or minimum working radius

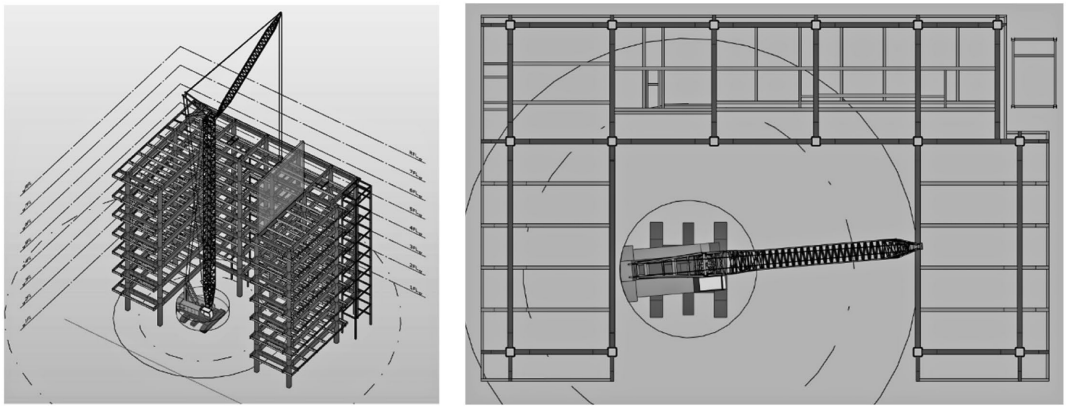

Fig. 6 Turning area view

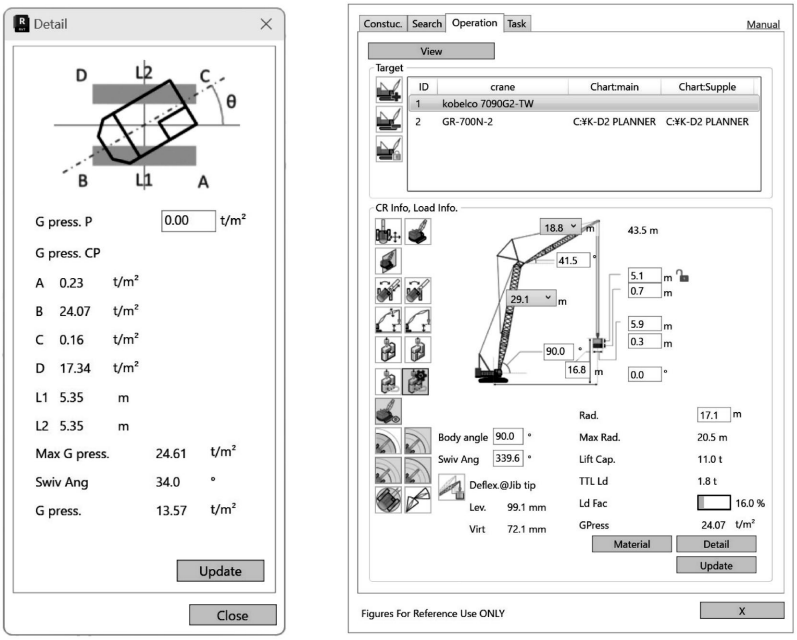

Fig. 7 User interface

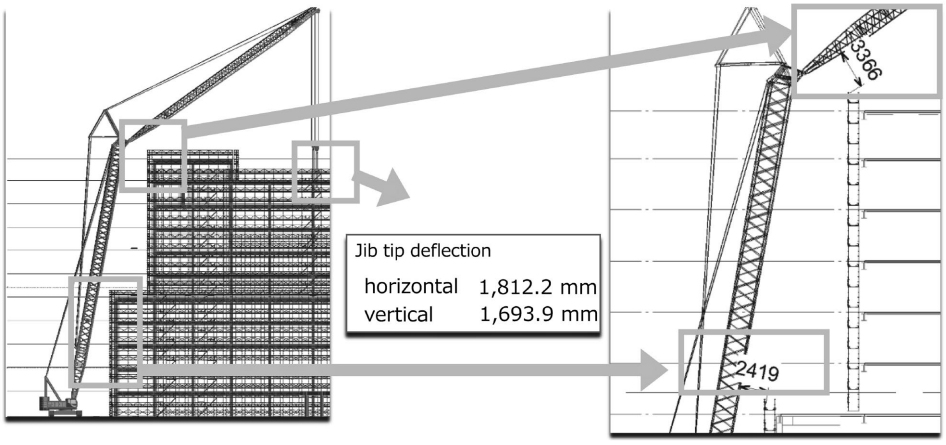

Fig. 8 Interference check with deflection

crane tipping.

K-D2PLANNER® automatically calculates and displays the load factor and ground pressure when the user simply selects the material to be checked in the BIM model of the steel frame. This makes it easy to evaluate the feasibility of parameters during construction planning through iterations of trial and error based on differing conditions such as crane type and specifications, target materials, and lifting conditions. The program can also be used to calculate the required ground reinforcement and steel plate thickness at the crane's operating location, substantially reducing time and improving accuracy in construction planning in comparison with capacity charts or 2D CAD.

Recent years have seen an increase in the use of precast concrete materials as well as the use of heavier materials. These factors are significant because crane boom deflection is based on the weight of the material being lifted. If the crane boom will be near the building, yet boom deflection is not considered during planning, the boom could contact the structure during operations.

K-D2PLANNER® can visually display crane deflection based on the load to be lifted. **Fig. 8** shows an example of a simulation that accounts for deflection. The jib tip deflection is 1812.2 mm in the horizontal direction and 1693.9 mm in the vertical direction, yielding approach distances of 2419 mm between the boom and the structure and 3366 mm between the jib and the structure. In this way, it is possible to check interferences and separation distances between temporary scaffolding and the crane boom in a way that accounts for deflection and

does not rely on expert knowledge.

Tracking the details of each step of the construction process chronologically also provides key verification capabilities. For instance, it is possible to visually check whether there is interference between the steel structure and the crane boom or superstructure as the building structure is assembled.

2.3 Preparing construction drawings

Construction drawings contain key information such as boom length, working radius, and the location of the crane in relation to the structure. These drawings facilitate team communication to ensure smooth, error-free construction. With K-D2PLANNER®, the user can create an automatically generated cross-section along the length of the boom by simply selecting the material to be lifted and clicking the icon to create a cross-sectional view. In addition, a crane operating range diagram can be superimposed, which is useful when drafting construction work plans as required by Article 88 of the Japanese Industrial Safety and Health Act (**Fig. 9**).

2.4 Compatibility with numerous cranes

K-D2PLANNER® comes pre-registered with BIM models of Kobelco Construction Machinery's main crawler cranes (50 to 500t class) (**Fig.10**) for loading into this CAD software. The pre-registered crane BIM models have capacity information, enabling operators to simply view the results of load factor calculations.

The full selection of pre-registered crane BIM models satisfies the needs of many construction sites in Japan. These models include rough terrain cranes and all terrain cranes manufactured by Tadano Ltd. (13 to 700t class) and KATO WORKS CO., LTD. (13 to 400t class) as well as crawler cranes manufactured by Sumitomo Heavy Industries Construction Cranes Co., Ltd. (55 to 500t class) (**Fig.11**).

Other cranes, such as tower cranes, must also be accounted for in construction planning. With some processing, it is possible to import crane BIM models prepared by construction machinery manufacturers under the initiative of the Japan Federation of Construction Contractors and by general contractors and other companies that provide construction planning services. Ground pressure and deflection

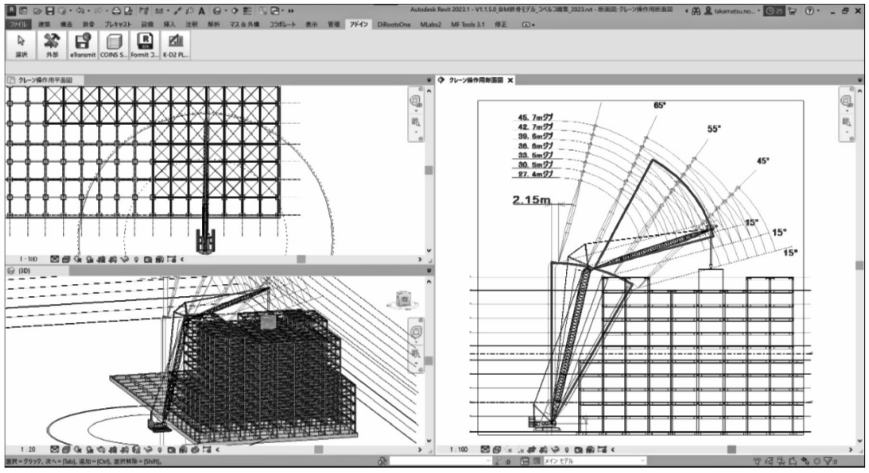

Fig. 9 Crane operating range on cross-section view

Fig.10 KOBELCO models

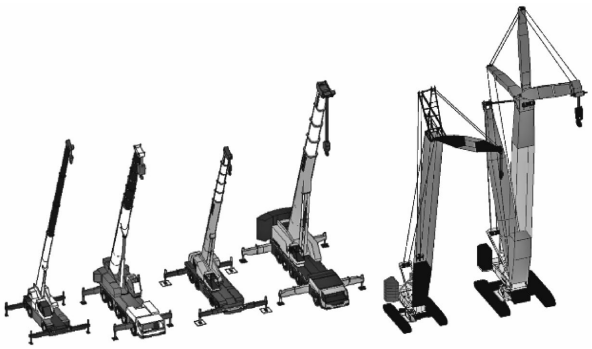

Fig.11 Other models

can only be automatically calculated for Kobelco Construction Machinery's crane BIM models, though.

2.5 Crane selection support

If the capacity of a crane is insufficient during construction, it must be swapped out, extending the construction timeline. Conversely, if the capacity of a crane is too high, this increases the cost of construction. As such, selecting cranes appropriately is important.

After the user enters the crane location and the material to be lifted in Revit, the system determines the material's position to enable searching for appropriate cranes and specifications. It is also possible to stipulate multiple conditions for the search. **Fig.12** shows such an example, in which the crane can be selected from three models (200t old model, 200t latest model, and 350t model) based on load factor and whether there is interference between the crane and the structure. This functionality supports the selection of the optimal class of crane, minimizing the footprint required for equipment and for dismantling and construction, and thereby minimizing construction costs.

2.6 Use in presentations

K-D2PLANNER® can register 3D construction plans as four-dimensional information by adding data arranged chronologically by construction step, enabling on-demand visualization of the results of construction plan reviews. In the project shown in **Fig.13**, space constraints prevent the positioning of cranes around the building, so the proposed procedure is to construct the building from the interior at the rear, working in the forward direction. In such a situation, it is beneficial to present a visual representation of the construction procedure at construction planning meetings. Such images make it possible to efficiently share information regarding the layout and construction plan, which prevents reworking due to misunderstandings. In addition, the construction procedure can be output to Navisworks, an Autodesk viewer program. This program makes it possible to view the entire project using Autodesk's architectural 3D CAD, facilitating the sharing of construction plans based on four-dimensional information at the construction site.

3. Effectiveness in construction planning

General contractors and similar parties using K-D2PLANNER® in the crane construction planning process reported the benefits below.

- Benefit 1: A model of the crane itself is necessary for crane construction planning using 3D CAD. This requires the services of a specialist, and the cost of creating a model is approximately 1500

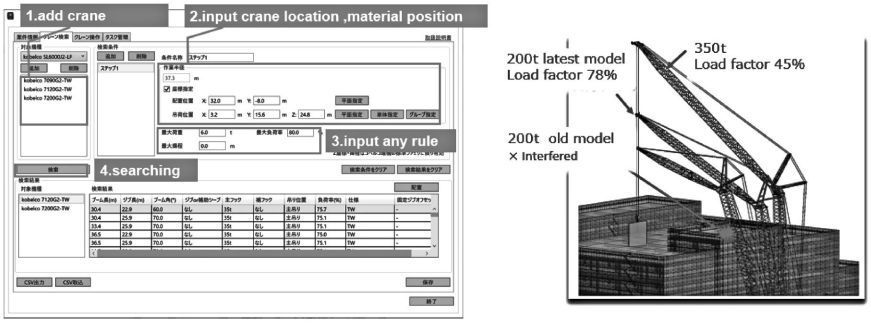

Fig.12 Crane search interface and result

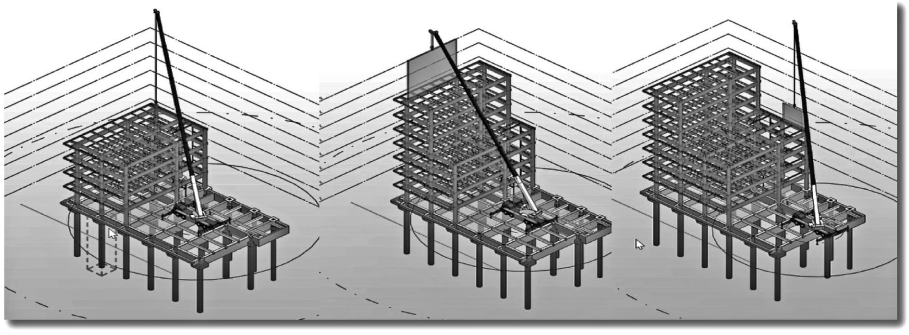

Fig.13 Construction procedure

USD per model. Maintenance is also required for new and discontinued models. However, K-D2PLANNER® contains models sold by major Japanese construction equipment manufacturers such as Kobelco Construction Machinery, Tadano Ltd., Sumitomo Heavy Industries Construction Cranes Co., Ltd., and KATO WORKS CO., LTD. With a total of 57 models, this software eliminates about 11.4 million JPY (80,000 USD) in model creation and maintenance costs (**Fig.14**).

- Benefit 2: By selecting optimally sized cranes using K-D2PLANNER®, rental fees for mobile cranes plus operator can be reduced from, for example, about 2.4 million JPY (17,000 USD)/unit/month for a 120t crane to about 2 million JPY (14,000 USD)/unit/month for a 90t crane, based on the February 2023 issue of construction material pricing report published by the Construction Research Institute. For a site that is active for 10 months, the total savings amounts to 4 million JPY (28,000 USD) (**Fig.15**).
- Benefit 3: K-D2PLANNER® eliminates modeling time and reduces construction review time by 40%, resulting in a 66% reduction in construction planning time (**Fig.16**).

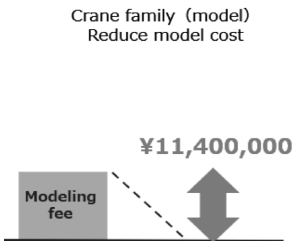

Fig.14 Benefit 1

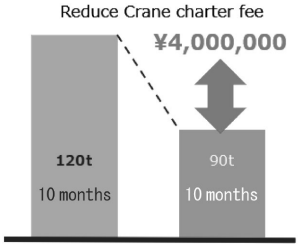

Fig.15 Benefit 2

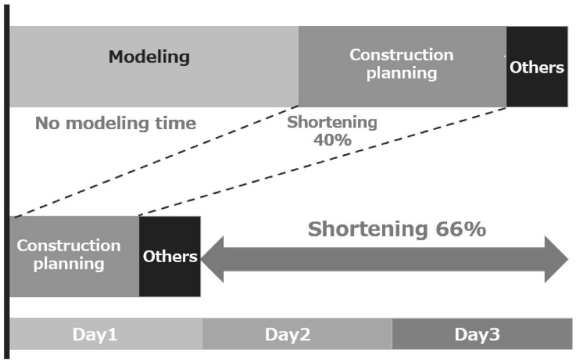

Fig.16 Benefit 3

A further benefit is the ability to verify the quality of the construction plan without relying on the expertise of the construction planner. As such, the quality of the construction plan and the construction project itself improve, and costs are reduced by preventing reworking.

In addition, the use of add-in software such as K-D2PLANNER® facilitates the use of BIM construction planning. General contractors and adjacent professionals anticipate that this will promote the use of BIM by eliminating barriers to incorporating BIM into the construction planning process.

Conclusions

The future of building construction will change drastically through the use of BIM for everything from design and construction to maintenance and management. K-D2PLANNER® is an intuitive program that unites design and construction in crane construction planning using architectural CAD by providing easy access to all information needed in a way that does not necessitate extensive expertise. We have incorporated numerous functions into the program in response to feedback from our wide range of users, from general contractors to plant and bridge engineering companies. We are developing new functionalities based on the further requests of our users and anticipate that additional needs will surface as the number of users increases. Our continuous improvements, added functionalities, and establishment of and research into standards for effectiveness will further promote BIM utilization in construction work.

References

1) Japan Construction Machinery and Construction Association. Construction Machinery and Construction 2023, Vol.75, No.1, pp.41-44.