Geotechnical Design from the Inside Out- Development of Automation Design Platform and BIM of MRT Geotechnical Engineering

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Abstract

Since 2011, countries around the world have started digital transformation after industrial revolution through automation and intelligentization. MRT engineering should also be transformed to automated and intelligent design. Owing to the complexity and huge amount of work within a limited time, MRT engineering design usually produces an inferior quality. Besides, geotechnical engineer design is placed at the end of whole MRT design process, so the tight schedule and heavy workload always trouble geotechnical engineers. Therefore, improving work efficiency and design quality by digital methods, preserving technical data, and checking the design accuracy become the main motivations for SINOTECH to develop design platforms. To put the digital transformation into practice, SINOTECH has developed three user-friendly website platforms, which are SinoExcavation, SinoTunnel, and SinoPipe. The standardize interface of input, output, and data validation reduce human errors. Furthermore, NTU BIM Research Center assisted SINOTECH in developing APIs to transform design parameters into BIM models automatically. In addition, the quantity calculations and conflict evaluation can be done by utilizing BIM model.

Keywords: Deep excavation, Design automation, Taipei MRT, BIM

1 Introduction

Since 2011, as the advancement of science and technology, the Industry 4.0 has redefined the Manufacturing Industry. However, in the Construction Industry, management consulting McKinsey & Company published a paper titled “Imagining construction’s digital future.” It pointed out that due to the complexities of large-scale constructions, the delayed projects, low margins, and poor business processes were reasons to be changed. According to the digital transformation defined by International Data Corporation (IDC), digital transformation is a method to improve work efficiency, lower the cost, and optimize the customers’ feeling by digital tools. Hence, the digital transformation seems like the solution to transform large-scale constructions.

From 2017, SINOTECH has started to wonder what is the best way for a Consultant Company to do a digital transformation. Therefore, SINOTECH established a BIM & Innovation Committee in 2018, and involved intelligence and automation to revolutionize all design tasks (standardize, automatize, and platformize the design process). Since then, SINOTECH has developed SinoExcavation, SinoTunnel, and SinoPipe website platform, and collaborated NTU BIM Research Center on Application Programming Interface (API) development. These APIs can link up analysis software and BIM software with Sino-

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platforms, and with user-friendly interfaces, this tool is able to reduce human errors and increase work effectivity. The auto-generated BIM models from standard worksheets have many other applications that can improve our design quality. Additionally, all design parameter and all empirical references are well preserved in Sino-platforms can also provide the database for future designers to check their results.

2 Sino-Platforms and Applications

The SINO-Platforms is the compilation of several platforms that was already planned by SINOTECH. Currently, from its plan there are 3 platforms that have been developed, which are Sino Excavation, SinoTunnel and Sinopipe. Each platform is specialized in one design scenario and targeted to increase work effectiveness and reduce errors.

2.1 Deep excavation engineering assisted by BIM automatic design (SinoExcavation)

In the traditional design process of deep excavation, designers needed to go through multiple Excel sheets to calculate, and managed each version were difficult. Moreover, the analysis results and the experiences might not be well preserved for the future use; also, the quantity calculation and quality control were time-consuming process. Therefore, SINOTECH has redefined the 3D design process to prevent these circumstances in the future. The design stages: (1) Automatic deep excavation design and analysis, (2) Automatic BIM generation, (3) BIM applications, (4) Data base and feedbacks.

2.1.1 Automatic deep excavation design and analysis

Instead of using multiple Excel sheets, all the calculations are done inside the SinoExcavation platform. This can help to organize each calculation. The platform provide a user-friendly interface that guides its user on step-by-step deep excavation analysis, started from inputting soil strata parameters and ground water levels, computing excavation safety (toe stability analysis and excavation surface stability), determining construction sequence, and finally analyzing wall and supporting system stresses.

To analyze retaining wall and supporting system stresses, SINOTECH usually employs geotechnical calculation software for excavation purposes, i.e. RIDO. This process is very time consuming, since the analysis need to be optimized. To ease this cycle, SINOTECH has developed a Windows Forms (Winform), which can iterate RIDO analysis automatically. In each iteration, both strut section and its preload forces are check and adjust automatically. The optimized RIDO results are uploaded to SinoExcavation platform, and the important results are presented in the platform pages, which are shown in Figure 1. Based on these results, designer can design the retaining wall and other supporting system. After doing all the calculation, SinoExcavation can automatically generate design report for this retaining wall type.

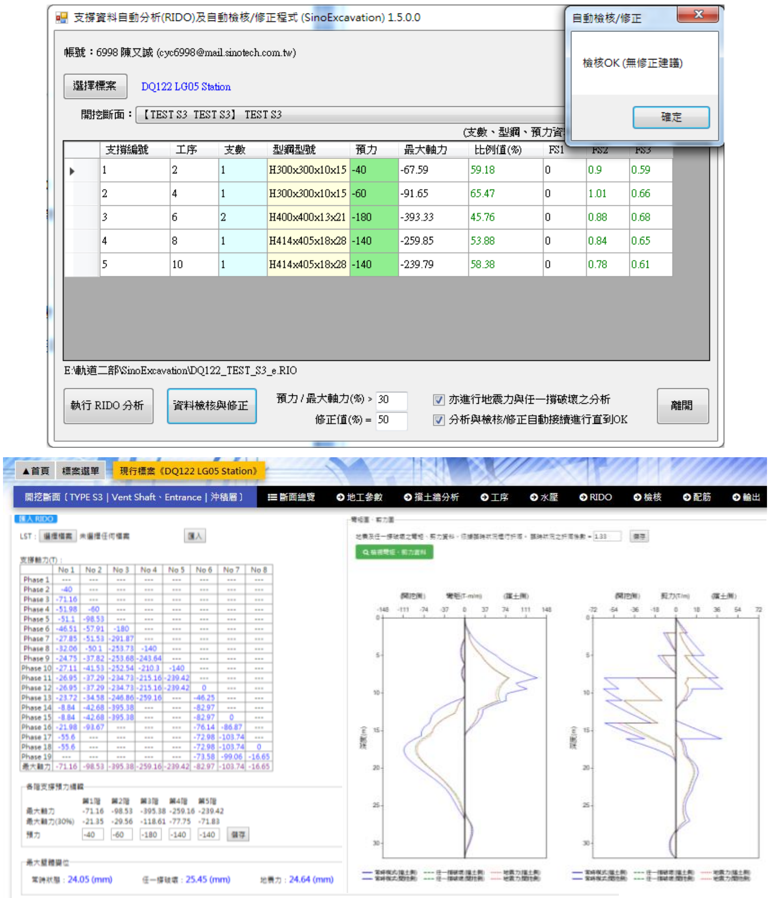

Figure 1: (Left) The Winform interface, which can automatically call RIDO to conduct the iteration itself (Right) The analytical results will be kept in SinoExcavation platform

2.1.2 Automatic BIM generation

After concluding the stage (1), SinoExcavation also can generate standard sheet, containing all excavation model information, including diaphragm wall and all supporting system members. Then input the sheet and diaphragm wall 2D drawing plan into SinoExcavation REVIT API to automatically build the BIM model, which is shown in Figure 2.

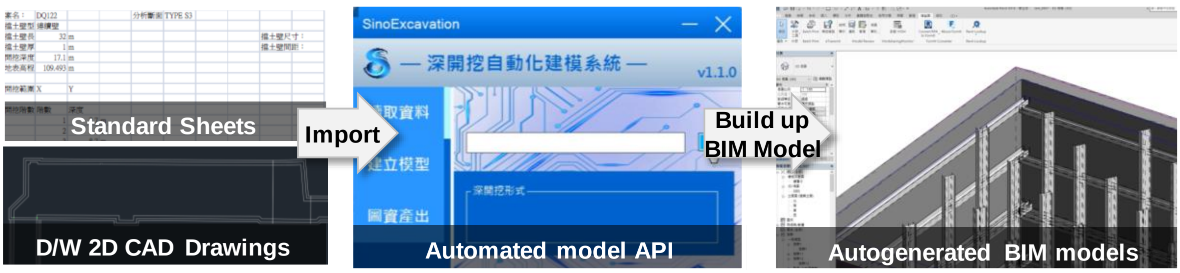

Figure 2: The process and interfaces of SinoExcavation auto-generate BIM models

2.1.3 BIM applications

From the generated BIM model in Stage (2), we can the same use API to draw 2D drawing. Furthermore, it can also generate a quantity calculation report base on the current model. This automated program has helped reducing errors. Moreover, this BIM model can help to do conflict management and 4D simulations, which is shown in Figure 3.

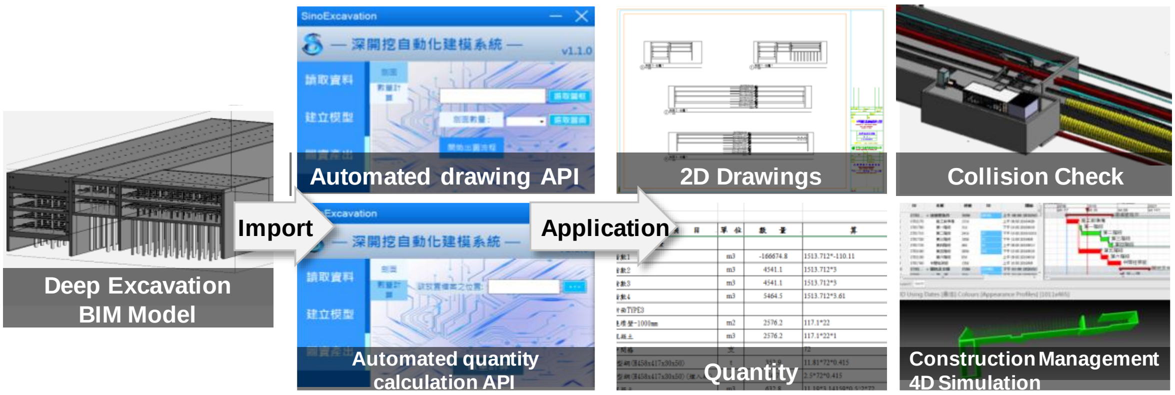

Figure 3: Applications of BIM models

2.1.4 Data base and feedbacks

Since all workflows are done within SinoExcavation platform, every design parameters, analytical results, and reports from a project is automatically archived in the platform. Furthermore, all the previous projects that was designed by SINOTECH can be inputted into the platform to further broaden its database. This excavation database can be used as training tools for the future designer. Also, the past study about deep excavation design and analysis from Zhan (1992), Ou et al. (1993), Hsieh et al. (1996), Ji et al. (1999), Wang and Hsieh (2007) has been included into the platform which can help to verify our design., please see Figure 4.

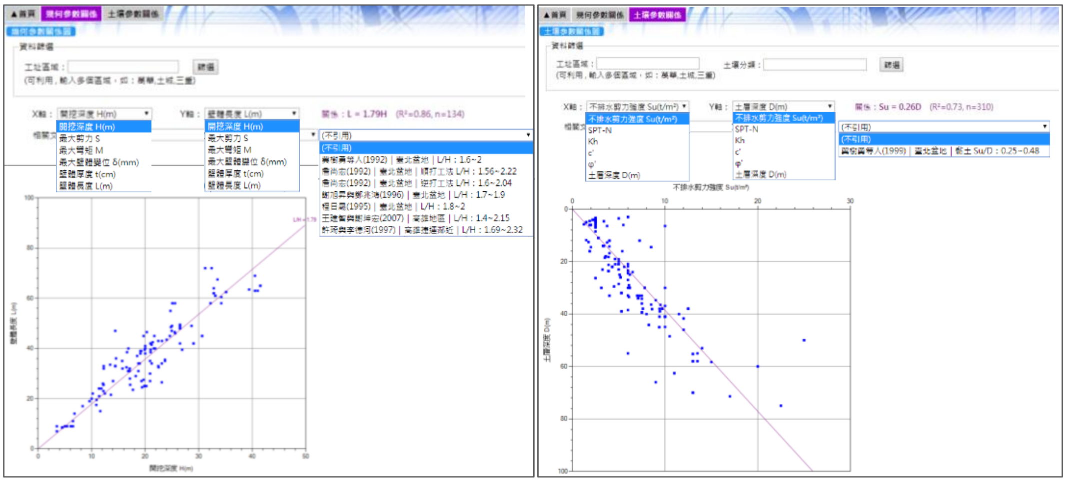

Figure 4: Past study and project data about deep excavation design are included into the platform

2.2 Shield tunnel engineering assisted by BIM automatic design (SinoTunnel)

There are the same difficulties as deep excavation when it comes to shield tunneling design, such as: multiple Excel sheets, all previous design parameters need to be collected manually and hard to make use as a reference. Similar to deep excavation, there are 4 stages on how SinoTunnel can improve design workflows.

2.2.1 Automatic shield tunneling design and analysis

Before inputting into the SinoTunnel, The dynamic envelope and vehicle clearance envelope are needed to firstly generated, which is based on each alignment and Metro planning manual. This procedure is done to confirm whether the tunnel internal space is sufficient. Only then, process to design shield tunnel lining can be carried out. In the design phase, the stress analysis by simulating several different load conditions on to lining was done in the structural analysis software, SAP2000. To simplify the iteration process, SINOTECH has also developed a Winform interface, which can automatically call SAP 2000 to conduct iteration, which is shown in Figure 5. Lastly, the final convergence results will be kept on SinoTunnel platform (Figure 6), to provide data for further safety analysis and section design.

Figure 5: The Winform interface, which can automatically call SAP 2000 to conduct the iteration itself

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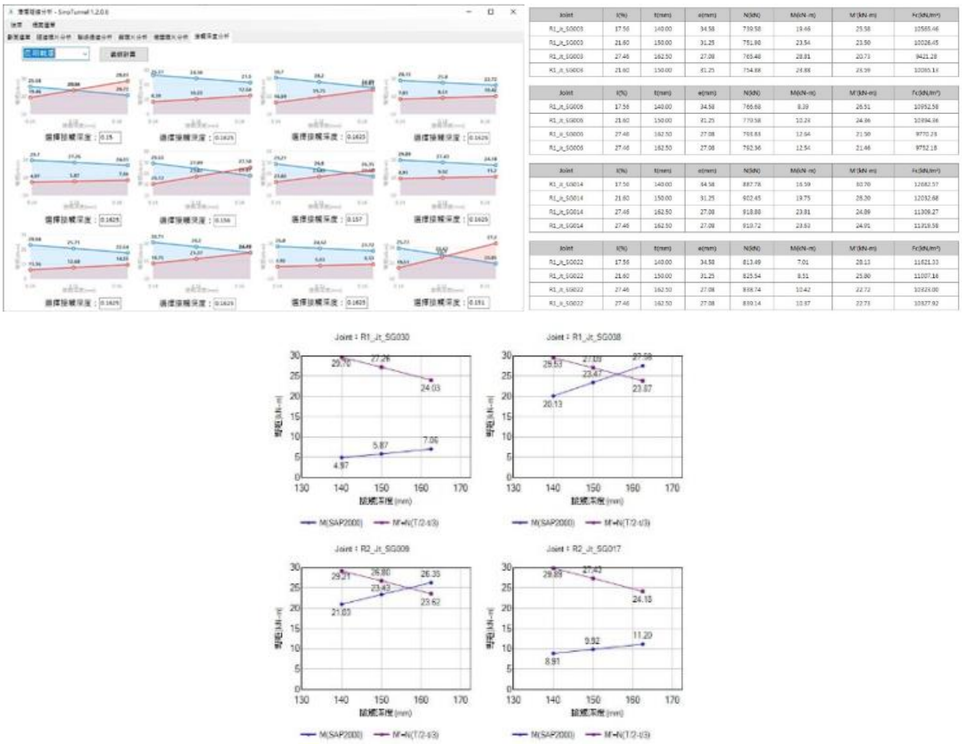

Figure 6: The analytical results will be kept on SinoTunnel platform

2.2.2 Automatic BIM generation

From stage (1), SinoTunnel platform records all design parameters (i.e. tunnel lining's diameter, width, thickness, etc.) from analytical results. The supplementary information, such as alignment, cant, invert, walkway, track bed, etc also need to be inputted into the platform. Only then, the standard sheets, containing shield tunnel model information, can be downloaded from SinoTunnel platform as the main input for REVIT API to build BIM Model. All of these processes are summarized in Figure 7.

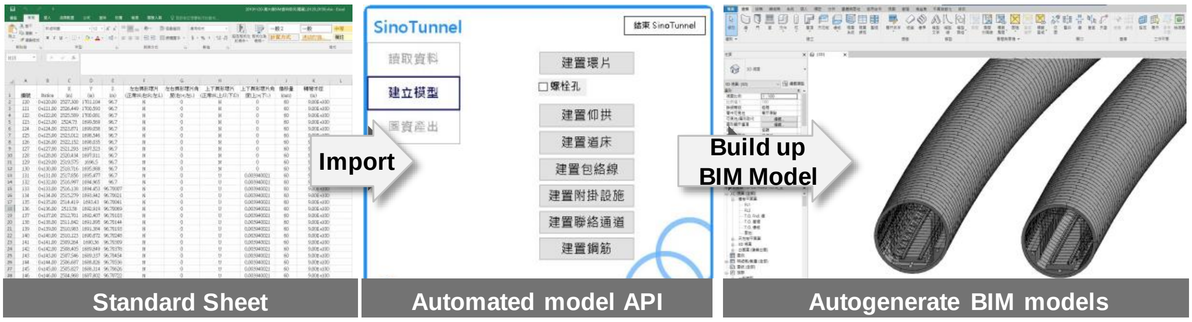

Figure 7: The process and interfaces of SinoTunnel auto-generate BIM models

Numbers of tunnel BIM elements generated by the API are enormous and complex. In summary, the items and models are listed below and shown in Figure 8:

A. Segments and invert: FST invert, standard track invert, ditch, and walkway

B. Track bed: floating slab track (FST), standard track, rails, and conductor rail

C. Envelopes: dynamic envelope, vehicle clearance envelope, and conductor rail envelope

D. Tunnel ancillaries, cross passage, and rebar

Besides, if some design components need to be revised, the relations between envelopes and the shield tunnel need to be examined all over again. Through the auto-generated envelopes, designers can check the conflict at all times, which make this workflow much more efficient.

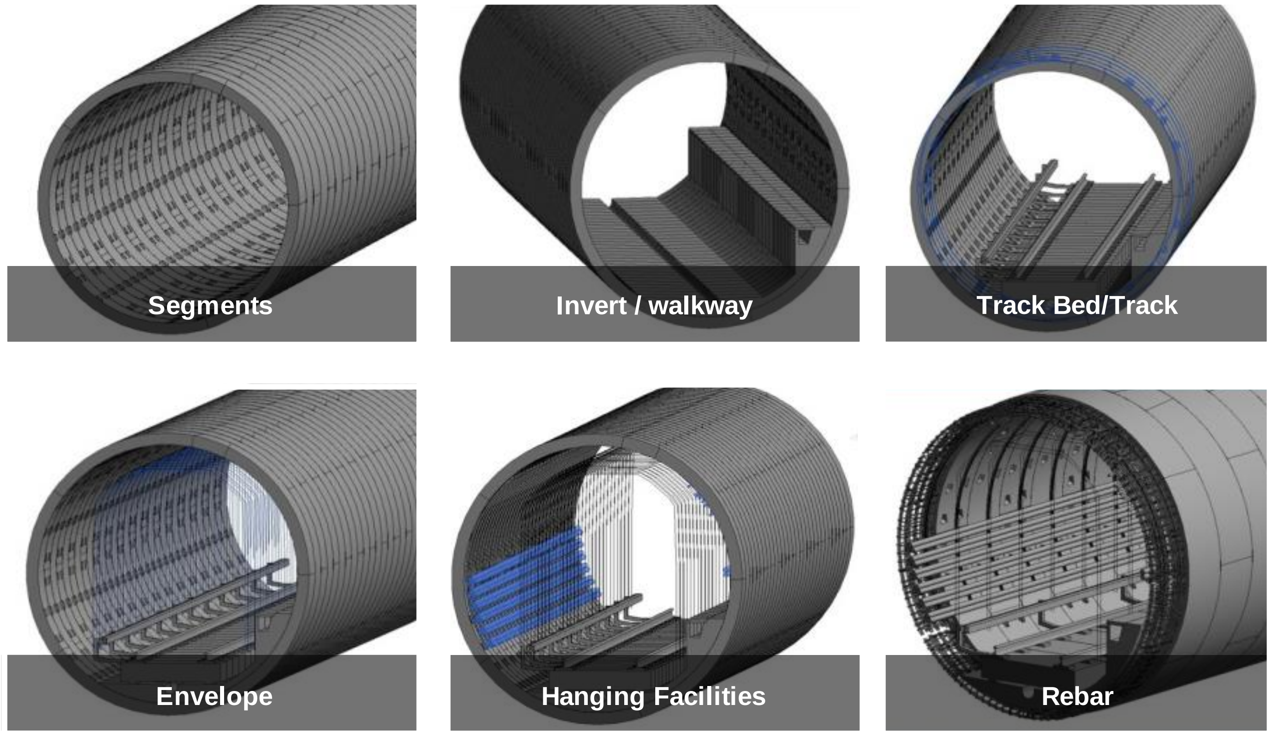

Figure 8: All kinds of tunnel BIM elements

2.2.3 BIM applications

After we finished building BIM models in stage (2), BIM models can be transferred into 2D drawings by using the API. Moreover, the quantity calculation reports can also be generated through the API (Figure 9). When there are some modifications in the design, all the corresponding data will be revised instantly, which can efficiently assist designers to examine their results.

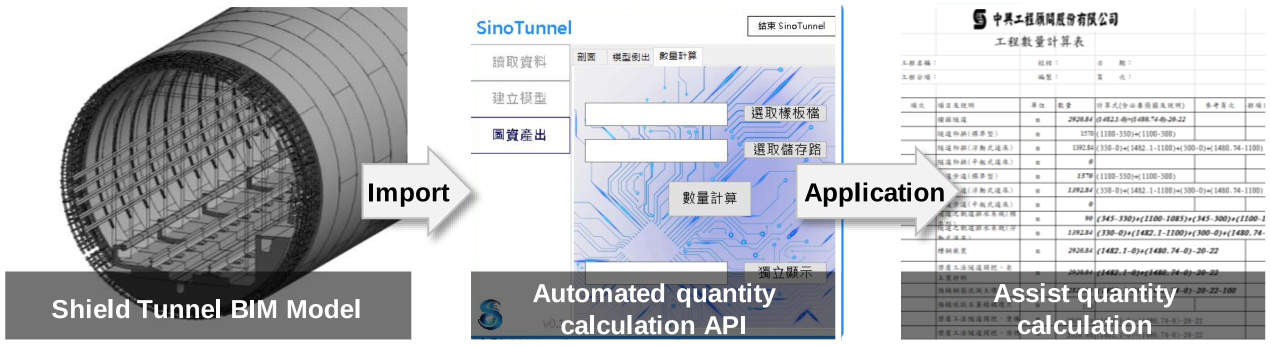

Figure 9: The process and interfaces of SinoTunnel auto-generated quantity calculation

2.2.4 Data base and feedbacks

With the assistance from SinoTunnel, all the design information involves envelope data, shield tunnel data, and BIM data, can be well preserved on the platform. Similar to SinoExcavation, the SinoTunnel contains analysis references and specifications that are carried out according to AFTES (2005), JSCE

(2007), DAUB (2013), ACI (2016), etc. Therefore, designers can apply the analysis precisely based on these experiences and feedbacks (Figure 10).

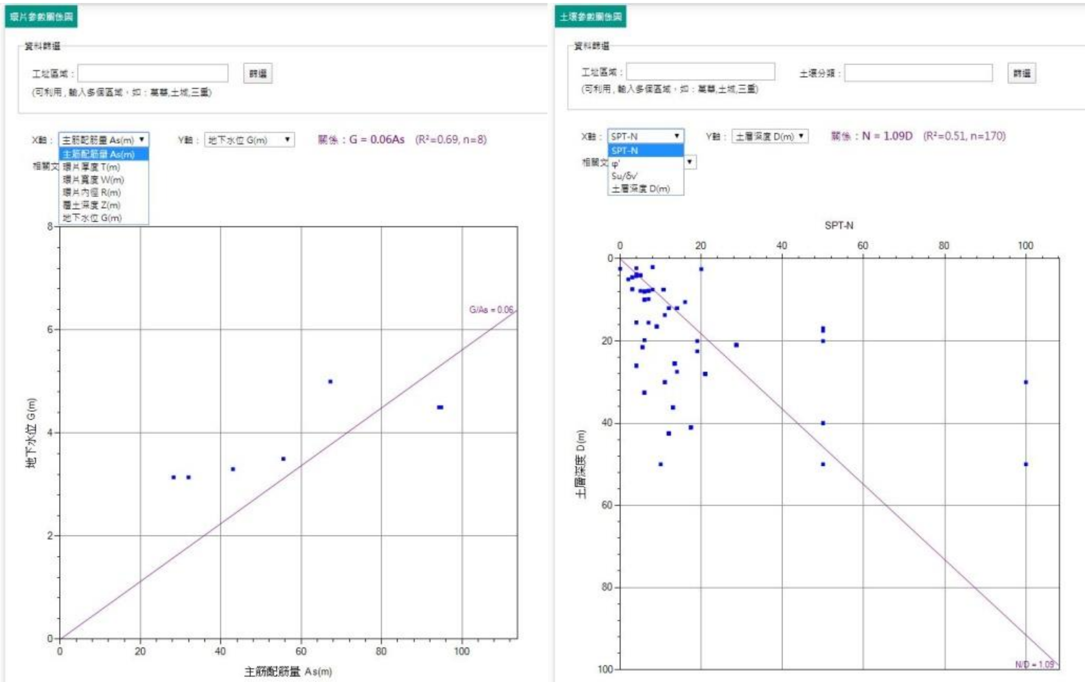

Figure 10: Past project data and specifications about shield tunneling design are included into the platform

2.3 Pipeline engineering assisted by BIM automatic design (SinoPipe)

There are multiple underground pipes like sanitary sewer, foul sewer, rainwater drains, etc, which are our daily life necessity. However, with the increasing amount of pipes and the underground space is limited, the spatial relations and database creation of pipes become urgent and essential. Hence, SINOTECH has evolved into a 3D automatic system named SinoPipe. We replace the old procedure with new concept to shorten the design period. More importantly, the considerable database can be well organized on the platform, and allow designers to integrate in their design.

The SinoPipe working stages are as follows: (1) Input pipe database, (2) Automatic BIM generation, (3) BIM applications

2.3.1 Input pipe database

We start up a series of standard sheets, and each sheet contains the identities of pipes and manholes. The sources of these identities can be divided into two types, survey data and 2D CAD drawings (see Figure 11).

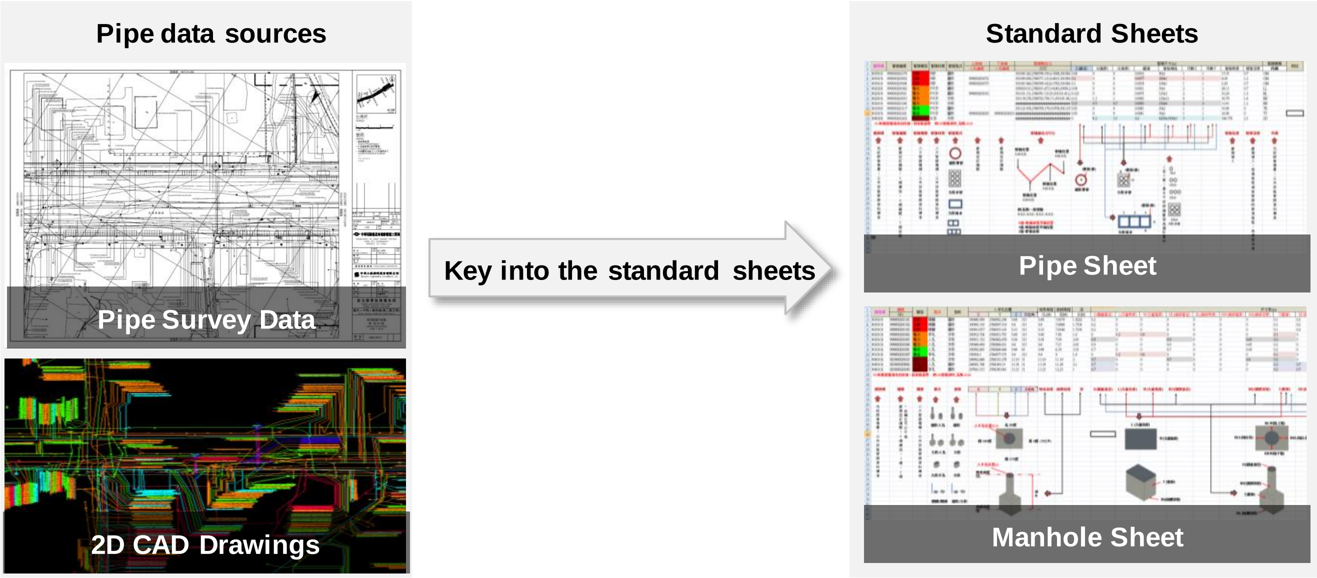

Figure 11: The process from input data to standard sheets

2.3.2 Automatic BIM generation

Through the API, the sheets can be transfer into BIM models, like tubes, box culverts, manholes, and valves. After that, we can import the existing pipes models into BIM to evaluate overall status (see Figure 12).

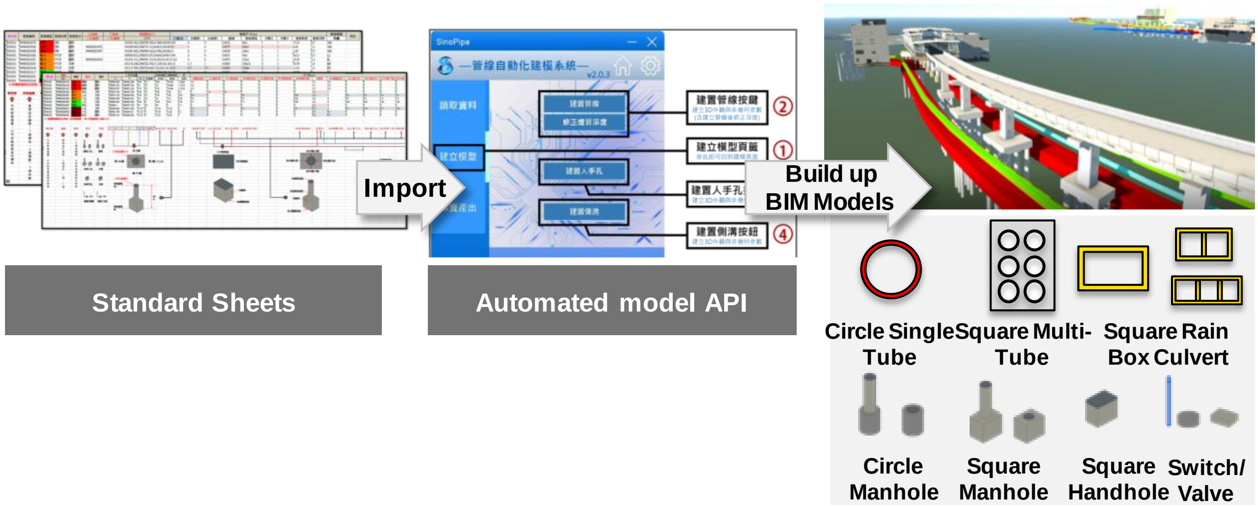

Figure 12: The process from standard sheets to BIM model

2.3.3 BIM applications

When we finished building BIM models from stage (2), we can then apply many other advance functions including collision check, 2D drawings, and quantity calculation. Moreover, we can combine tunnel models (from SinoTunnel) and pipe models (from SinoPipe) to come up with the composite cross section diagram, which can save more time of integrating different professions (see Figure 13).

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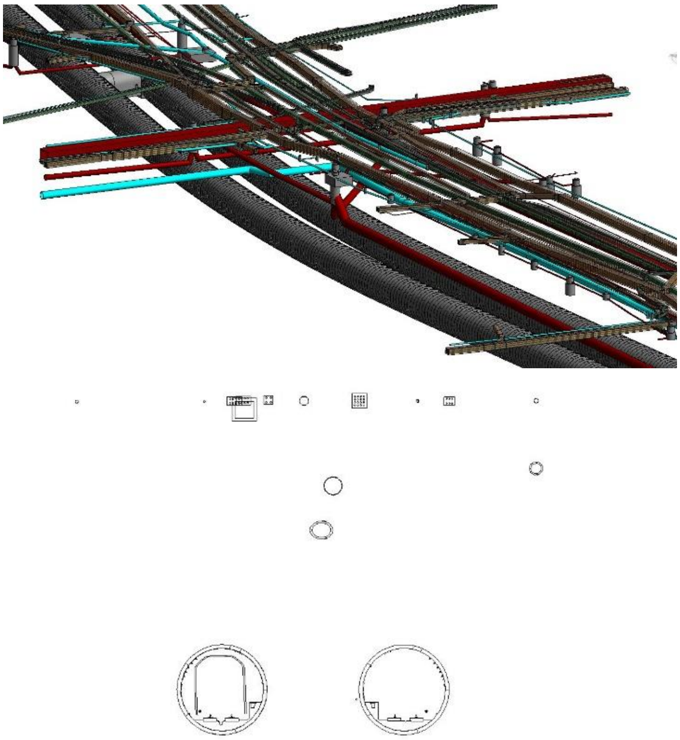


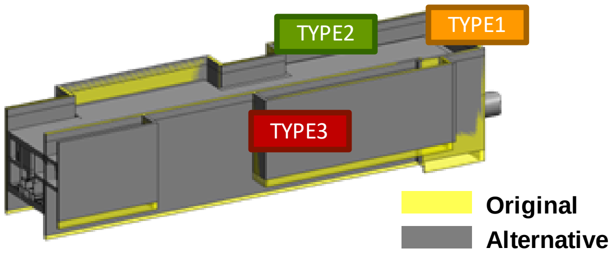
Figure 13: (Left) Tunnel models and pipe models, (Right) The composite cross section diagram

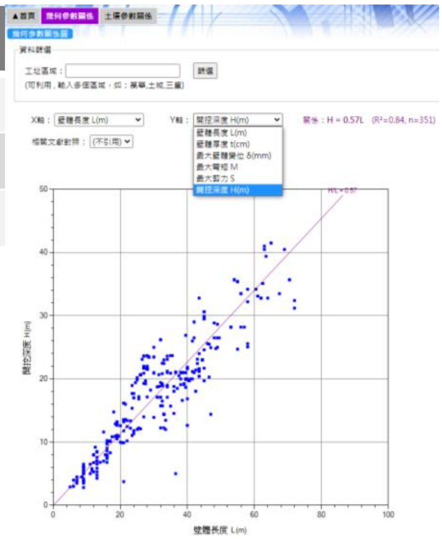
3 Case Study

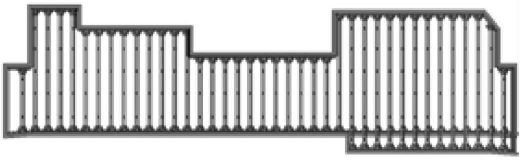
SINOTECH has put these Sino-platforms into practice, that is, we utilized these three platforms to fully design Taipei MRT detail design project. These platforms have significantly reduced the iteration time in comparison to the traditional design work flow. Furthermore, the automatic BIM model generation has also proved reduce all drawing and quantity computation time. Since all of these works has done in Sino-platforms, all data and experience were all recorded inside the platform, which can be used as references for other project.

In this project, the database has proven to be powerful tools when designing underground station's retaining wall system. These assessments from the previous projects has assisted us to reasonably shorten the wall length, and re-adjusted the strut spacing based on in-situ geological condition (see Figure 14). Additionally, the combined BIM models, from three platforms, has facilitated engineers to check conflict and lower the construction risk (see Figure 15).

D/W TYPE	Excavation depth	D/W Thick	【Original】 D/W Length	【Alternative】 D/W Length
TYPE1	21.75m	1.0m	28m	27m
TYPE2	21.75m	1.0m	28m	27m
TYPE3	13.55m	0.8m	23m	21m







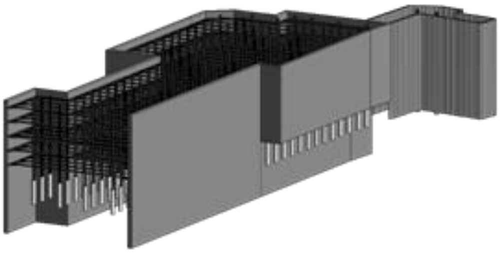


Figure 14: Use past design feedbacks to revise the diaphragm wall parameters

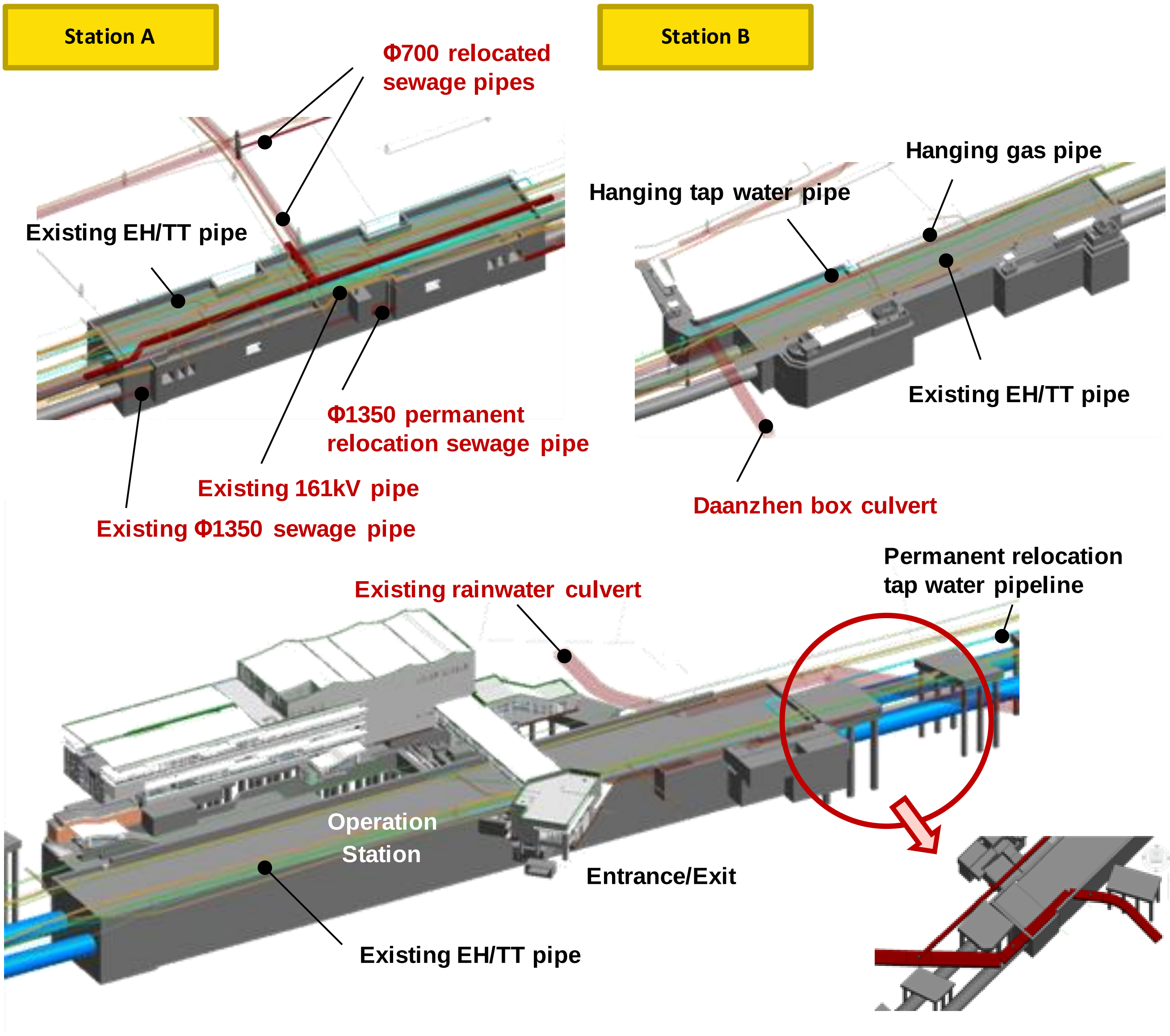


Figure 15: Collision check between structures and pipes

4 Conclusions

SINOTECH has led toward digital transformation by revolutionize the traditional 2D design, and using 3D digital simulation to redefine the construction design task. As mentioned, SINOTECH has been committed to reinvent whole design process by standardizing, automatizing, and platformizing.

First, standardizing makes our work more efficient by using a user-friendly interfaces platform. Secondly, with the automatizing, we can automatically generate 3D BIM models once the results are done analysis. Furthermore, each BIM element contains its own information, which can assist designers to analyze more effectively. Thirdly, due to the great amount of analytical data, we need a space to archive it. So, we built website platforms and input all the previous project data onto them, which can provide valuable references for future engineers. To do so, we expect that we can apply it into analysis precisely based on these experiences and feedbacks in the upcoming projects.

International Data Corporation (IDC) has predicted that the global digital transformation would enter into "Transform 2.0 generation" in 2020. The enterprise would focus on "Data-Driven" instead of previously "Digital-Led". Through the rapid growth of information and technology in 21st century, all works of life start to have the awareness of digital transformation, and propose to digitize the data and automatize all the operation. With the preserved data and information all these years, this database can be used as the basis of intelligence in the future. Apparently, the digital transformation also becomes the vital task to the civil engineering market. Hence, SINOTECH published this paper to introduce our progress as a breakthrough into digital transformation in construction industry.

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