Step towards Informatization Restrictive Factors and Strategies of BIM Technique's Popularization in China's AEC Field and Its Adoption in Professional Practice

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Abstract. Informatization is the foundation of intellectualization, and intellectualization is the guarantee of Industry 4.0. However, the informatization degree of the AEC (Architecture, Engineering and Construction) field is far lower than that of other industries, and the informatization rate of China's AEC industry lags behind the international level. BIM Technique, as one of the effective means to realize informatization in the AEC field, hasn't been well promoted in China with years of effort, especially among design teams. Taking Revit as the main BIM software in the AEC industry, this paper includes (1) the restrictive factors of BIM Technique's promotion and popularization; (2) the emergence of "Positive BIM Technology" and its effect on the strategies of BIM Technique's popularization; and (3) the adoption of "Positive BIM Technology" in different design phases of architectural professional practice.

Keywords: BIM; Positive BIM Technology; Design Phases; Architectural Professional Practice
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1 INTRODUCTION

BIM, building information model, integrates all kinds of building information into a virtual 3D model, such as the schedule, cost estimates, material inventories, geometry, and spatial relationships. The information, as data, allows all project members to efficiently collaborate throughout the whole project life for building analysis, project management, and construction simulation. BIM is the fundamental guarantee of standardization, informatization, and industrialization in the AEC industry. And it will effectively improve work efficiency, save social resources, reduce economic costs, and achieve sustainable development. Although there are plenty of benefits, the BIM implementation level in China is still low. To figure out the reasons behind and help BIM Technique's popularization, this paper focuses on three parts: first, the analysis of the reasons behind the low BIM

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implementation level in China; second, suggestions on BIM’s popularization; third, BIM adoptions in professional practice and the advantages. The third part aims to build up the confidence of the design teams for the BIM Technology Popularization.

2 ORIGINATION OF "POSITIVE BIM TECHNOLOGY"

2.1 Comparison of BIM Design Status between China and the United States

The United States is always at the leading position in the AEC industry informatization, while China is still at the primary stage. Figure 1 shows BIM adoption data in North America and China. According to the report by McGraw Hill Construction, the business value of BIM in North America (2007-2012), the BIM adoption in North America increased from 28% in 2007 to 71% in 2012; in 2012, the BIM adoption of construction firms reached 74%, surpassing that of architecture firms (70%) [9]. China's BIM implementation level (the proportion of projects applying BIM in the total project volume) in 2014 is far less than that in the United States in 2012, and less than 10% of firms reach a very high BIM implementation level (greater than 60%) [6]. But a similar trend for both China and the United States is that BIM adoption by construction firms is more prevalent than that by design firms, which indicates that BIM technology has large potential value [5].

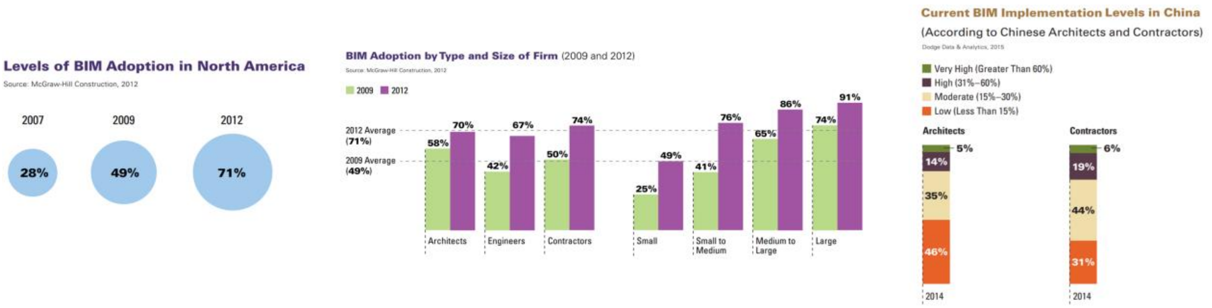

Figure 1: BIM adoption data in North America and China: (a) Levels of BIM Adoption in North America, (b) BIM Adoption by Type and Size of Firm in North America, and (c) BIM Implementation Levels in China.

Problems and losses caused by two-dimensional drawings have led project managers to look for new methods. Accordingly, the concept of Building Information Modeling (BIM), which is becoming increasingly common and evaluates a project in different dimensions, has emerged [4]. China, the world’s largest AEC market, is currently undergoing a growing demand on BIM utilization along with recently published governmental policies to enhance the BIM adoption [7]. During the past 15 years in China, a large number of projects' BIM models were made based on the construction documents drawn by AutoCAD, which has a specific name, "BIM Model Translation". In terms of the whole project process from design to construction, the way of "BIM Model Translation" does not take advantage of BIM Technology at all. Figure 2 gives an example of "BIM Model Translation". In this project, the design team used Rhino for massing design and AutoCAD for plans, sections, elevations, and details. After the construction team took over the work, they had to make the BIM model based on the 2D AutoCAD drawings either by themselves or by an outsource BIM team. When there was a need for revision, the same "BIM Model Translation" phenomenon repeated until the end of a project. But the construction team still adopts BIM because its 3D model and 2D drawing can't synchronize automatically.

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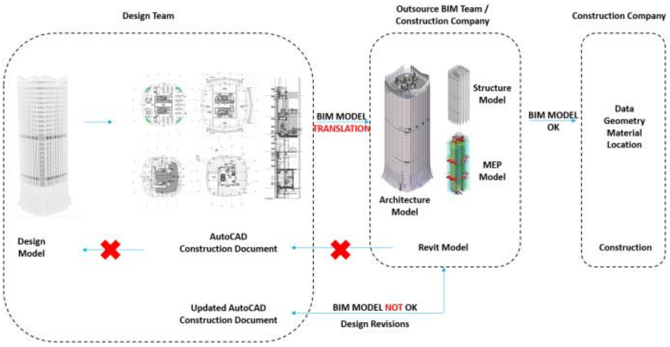

Figure 2: “BIM Model Translation”.

Figure 3 tells the different ways to get BIM models for construction firms in China. It is from the analysis of BIM application status in China's construction industry released by Glodon Company Limited (a digital building platform service provider in China) in 2020. The way for construction firms to get BIM models shows that nearly 80% of firms need to build BIM models by themselves, and only 8.87% of the models are provided by clients or design firms [8]. This number indicates that an enormous gap exists in the design firms' BIM implementation level.

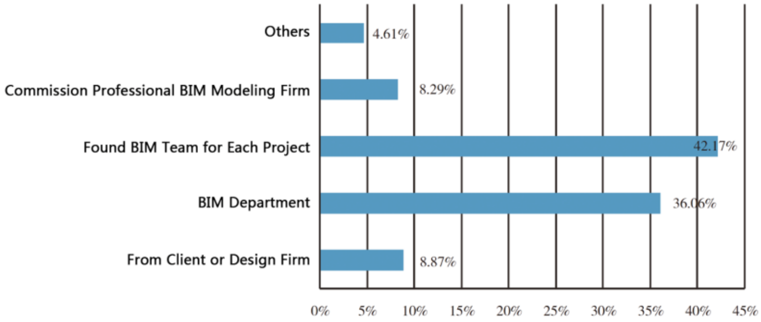

Figure 3: Different ways to get BIM models for construction firms in China.

The low rate of BIM implementation level in design firms indicates a gigantic waste from the perspective of the project's whole lifecycle. Only by introducing BIM technology in the design phase can we realize smooth data delivery in the entire industrial chain and the informatization of the AEC industry.

2.2 Restrictive Factors for the Popularization of BIM Technology in China’s Design Companies

BIM software is the carrier of BIM Technology. Taking Revit, the most popular BIM software, as an example, its popularization in design firms in China remains limited. Compared with the popularization of AutoCAD, which took only eight years to occupy that broad market, Revit’s road isn’t an easy one. From the release of Revit 1.0 by Revit Technology in April 2000 to today's Revit 2022 by Autodesk, after 20 years of effort, the application proportion of Revit in China is still limited, and so is the BIM Technology. Despite the numerous benefits of BIM, many companies are still reluctant to adopt it [10]. Three main restrictive factors are summarized by interviewing hundreds of professional engineers in design firms.

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2.2.1 Complex software operations and detailed pre-setting result low efficiency

Compared to AutoCAD's rapid and direct drawing workflow, which is much similar to the hand-drawing process, 2D drawings in Revit software are from 3D models. Complex software operations and detailed pre-setting result in low efficiency at the beginning of each BIM project. Many preliminary settings need to set before modeling, such as the elevation of each floor, the size of columns, and the type and thickness of walls. For design teams who get used to no more than a dozen AutoCAD commands to complete a set of drawings, the BIM way is less efficient in the early stage of work. They will have anxieties about the slow pace of the BIM project in the beginning due to the extra software work. So, it is difficult for them to choose Revit or other BIM software from their own initiatives.

2.2.2 Relying on the outsource BIM modeling firms brings high communication cost

Not many design teams in China are very skillful at Revit. For most projects that need a BIM model, it's regular for the design team to hire an outsourced BIM modeling firm to do the 3D work, while the design team still works on 2D by AutoCAD. These so-called "BIM" projects are not BIM at all, and the most valuable part of BIM — coordination among data, geometry, and the design team — is missing in this workflow. What's worse is that many BIM firms' employees are not from architecture-related majors, so they can't meet the design team's requirements. Thus, much communication cost happens, and it brings the intuitive feeling of "BIM Technology reduces work efficiency" to the engineers of the design firm, which heavily hinders BIM's popularization.

2.2.3 High initial investment cost but unclear tangible benefits

Revit model operation requires high-performance computers as well as skilled engineers. A design team needs at least a dozen or even dozens of computers and professional software training. In some cases, part of the work needs to be completed by the outsource BIM team, resulting in higher subcontracting costs. However, that high investment cost couldn't bring direct and obvious tangible benefits to the design teams who are not BIM experienced. As economic profits drive market activities, the short-sighted urge for quick money is the top restrictive factor for BIM's popularization. From this point of view, the fast pace of construction projects in China perhaps is the underlying reason.

2.3 Origination of "Positive BIM Technology"

Through the analysis of the above three constraints, the fundamental reason for the difficulty of BIM Technology promotion and popularization is that the design team does not really participate in the BIM design process, but relies too much on the outsource BIM firm. It brings negative results such as the "BIM Model Translation" phenomenon, increases communication and subcontracting costs, and decreases profits. These negative results make more designers reject BIM Technology. It turns into a vicious circle.

However, limitations of the AutoCAD mode will become even sharper with the constant technology development. Its low efficiency of information delivery is the main issue. Figure 4 is a contrast of the non-BIM model and BIM model on the information delivery path between the model and the drawing. For the non-BIM model, a large amount of repeated work results from the single-direction information delivery. Another issue is its unfriendly access to IoT and other high-tech applications. On the contrary, BIM's application to the whole process of the project will become a trend. It's urgent to complete BIM Technology popularization in the AEC industry.

"Positive BIM Technology" is specially proposed to distinguish the workflow from passively relying on the "BIM Model Translation". It aims at the early adoption of BIM Technology from the design phase, and targets the ultimate informatization of the AEC industry. Positive BIM Technology needs the design team to positively participate in the BIM collaborative design. This is significantly important as the design work is the base of a project.

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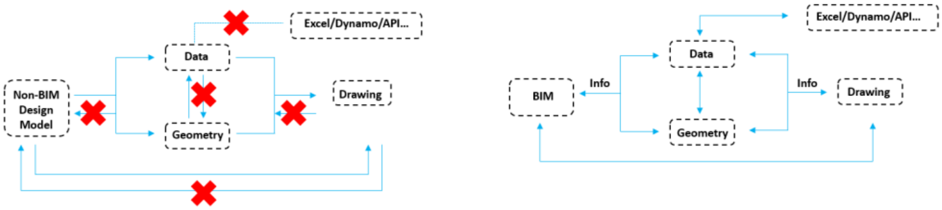

Figure 4: Information delivery path between the model and the drawing: (a) Single-direction information delivery for Non-BIM model, and (b) bi-direction information delivery for BIM model.

Figure 5 lists the benefits of the BIM model during the project's whole lifecycle, from the design phase to the O&M (Owners and Maintenance). The delivery of the BIM model accomplishes the delivery of information among the design team, client, construction team, and other product or service suppliers. It helps the whole AEC industry complete its informatization. According to the enlarged role of BIM during the project lifecycle process, "Positive BIM Technology" also has a great potential to connect with the IT industry, which makes full preparation for Industry 4.0.

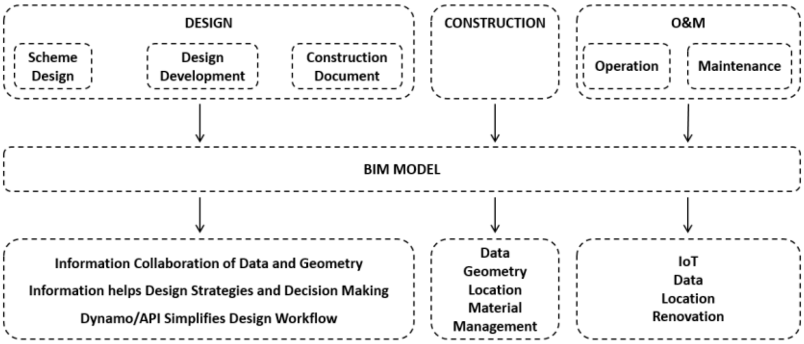

Figure 5: Benefits of BIM model during the project lifecycle.

3 BIM TECHNOLOGY POPULARIZATION STEPS BY POSITIVE BIM TECHNOLOGY

To guide the design team to carry out the positive BIM design method, we must first break down those three main restrictive factors in the following five steps.

3.1 Investment of Design Firms

The investment of design firms is the foundation of BIM Technology Popularization. The design firms need to have positive incentives for BIM's promotion and popularization, and direct the design team to actively adopt Positive BIM Technology from three aspects: production implementation, productivity, and production relations. For example, provide high-performance computer and software operation tutorials, reward those projects that adopted Positive BIM Technology, etc.

3.2 Evolution of Design Teams

The core strategy for BIM Technology Popularization is the evolution of design teams. Limited economic profits result from the incompatible relationship between AutoCAD work mode and BIM software tools. With BIM software's adaptive work mode, the design schedule can be shorter, economic profits can increase, and BIM Technology popularization can spontaneously turn into

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reality. Positive BIM Technology needs the design team fully participate in the BIM implementation, and evolve in thinking, workflow, collaboration, and project management.

Figure 6 shows the comparison of the design schedule for the same scale project (150000 m^2 office building) in the AutoCAD era and BIM era. On the left side, it is the recommended schedule in the AutoCAD era with experience from nationwide projects. On the other side, it is a professional practice project design schedule adopting BIM Technology from the scheme design phase. Scheme design and design development take longer in the BIM project, compared to the traditional AutoCAD project. But from the larger scheme of things, the whole design schedule of the BIM project is shorter indeed.

Figure 6: Comparison between the national architectural design cycle standard of office buildings with the scale of 150000 m^2 in the AutoCAD era and the actual design cycle of a Positive BIM Technology project in the same scale.

This project is an active attempt at Positive BIM Technology application by a design team equipped with almost zero BIM software operation skills (Figure 7). By forcing themselves to use Revit instead of AutoCAD, the design team provided a piece of engaging evidence that Positive BIM Technology is magnificently powerful in the design phase, with evolution in thinking, workflow, collaboration, and project management.

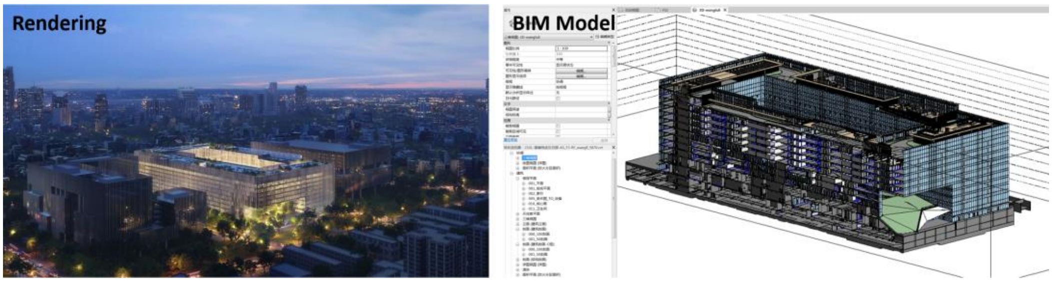

Figure 7: The project adopted Positive BIM Technology by a team with almost 0 BIM experience.

Three aspects contribute the most to this evolution:

(1) Establish the concept of "modeling first and then drawing", think in the way of 3D construction instead of 2D drawing, and adjust the project timetable for a longer period in the beginning.

(2) Adapt to the new work mode with real-time 3D collaboration and integrated document management. BIM's real-time 3D collaboration requires each team to fully consider all the related systems from the beginning, instead of focusing on each one's own field and documenting back and forth among different teams. Early adoption of BIM in the design phase might not benefit the team immediately, but it will get paid back by greatly reducing the workload in later phases and shortening the whole design process. Besides, compared to the rigid AutoCAD document management based on each system, the BIM document management can be flexible based on the organization strategy of the central model (Figure 8).

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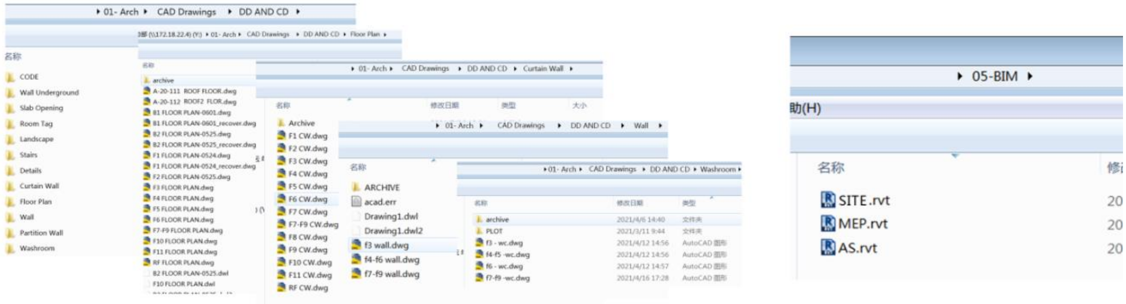

AUTOCAD Projects Management BIM Projects Management

Figure 8: Comparison of engineering drawing management system between AutoCAD and BIM: (a) AutoCAD Document Management for Architecture only, and (b) BIM Document Management for Architecture, Structure and MEP.

(3) Make full use of data via building simulation tools, most of which have friendly access to BIM software. The computational design method or data-driven design method will guarantee a rational design. Figure 9 gives several BIM-accessible examples of building simulation software, such as Simulation CFD (Computational Fluid Dynamics), Ecotect, Ladybug Tools, and Energy Plus.

Figure 9: BIM-accessible building simulation software.

3.3 Creation of BIM Work Environment

The informatization of the AEC industry relies on BIM Technology. It's necessary to create a BIM work environment for the whole industry. By positively using BIM since the scheme design phase, the design team will be more familiar and confident in BIM implementation; by compelling delivering the BIM model to different collaborators, the BIM environment begins to take shape gradually. Figure 10 illustrates the direct delivery of the BIM model through different teams, and the continuous development of the BIM model at different LOD (Level of Detail) during the project lifecycle. The form of the BIM model eliminates the various document formats, reduces the cost of the communication, and simplifies the workflow.

3.4 Cooperation with the Outsource BIM Team for Computational BIM

Make better use of the outsource BIM team to power up the work efficiency, rather than simply for modeling from AutoCAD to BIM. As the data and geometry coordinate correspondently in the BIM model, the inefficient and repetitive work in the AutoCAD era can be simplified now, even eliminated. With the help of developers from the BIM team, the collaboration between data and geometry can maximize the value of the information model by coding with python, Dynamo, C#, and so like. Figure 11 depicts how Revit and the coding environment work together. Excel can be the data organization tool for both input and output between Revit and the coding environment. Coding bridges the geometry and statistics in Revit. Dynamo is an open-source add-in for Revit.

There is a lot of such examples in design, and the logic of scripts is based on customer's requirements [12]. Figure 12 gives an example of a Dynamo script for the column tags' position control. All the tags will automatically update their positions once the parameter changes in the Dynamo script.

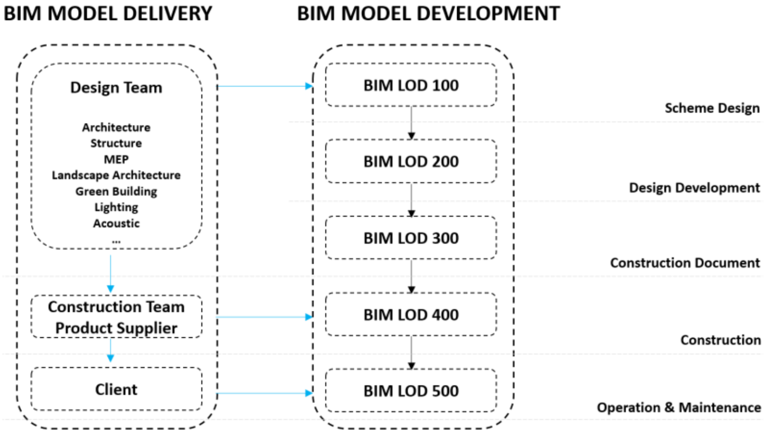

Figure 10: BIM model delivery and BIM model development during the project lifecycle.

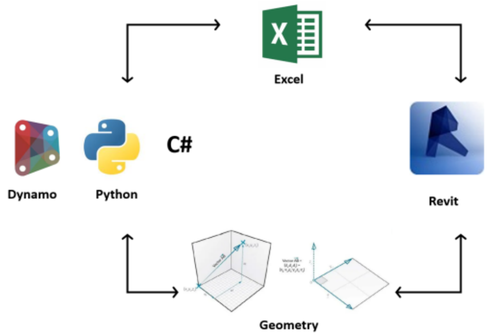

Figure 11: Revit and coding environment for data and geometry collaboration.

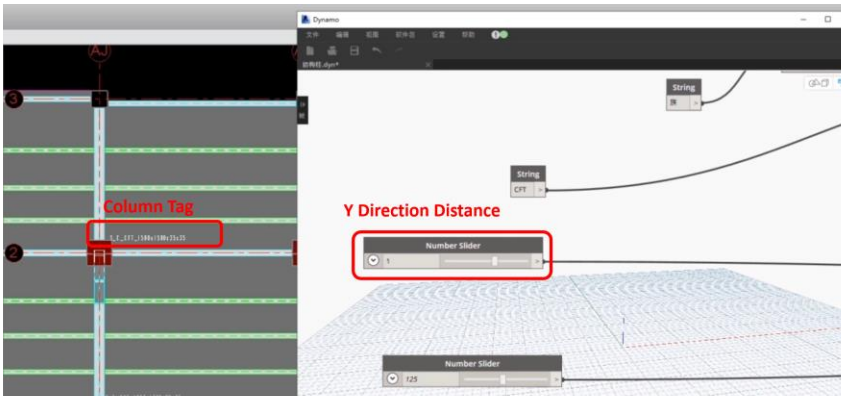

Figure 12: Dynamo script to control all the column tags' position.

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3.5 Development of BIM Library

The library for BIM templates and components should keep developing for future usage, along with the accumulation of BIM project experience and the working methods. Figure 13 is part of the component library developed during professional practice.

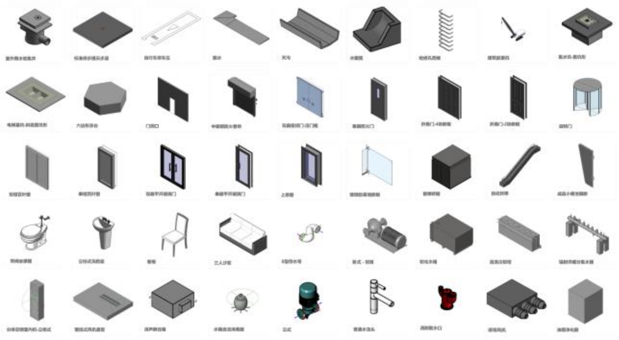

Figure 13: Components library.

4 PROFESSIONAL PRACTICE OF POSITIVE BIM TECHNOLOGY ADOPTION AND ITS ADVANTAGES IN DIFFERENT DESIGN PHASES

The design team and the BIM Technology support each other indeed. The earlier the Positive BIM Technology is adopted, the greater value it creates. While the design team makes the most of BIM, and BIM Technology Popularization comes true in return. Figure 14 shows that all phases during the whole design process can adopt Positive BIM Technology, and exhaust the value of the BIM model. Throughout the design process of a project, from the schematic design phase to the construction documents phase, each phase has its key points on BIM adoption.

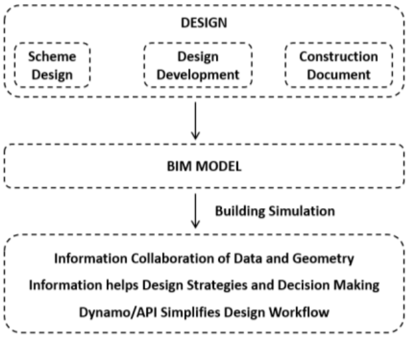

Figure 14: Positive BIM Technology adoption during the whole design process.

The following examples are from the project (Figure 7) by a design team with 0-BIM experience, which gives a glance at how they can finish this project by adopting Positive BIM Technology. These BIM implementations in professional practice work might eliminate the low-efficiency and complicated impression of BIM adoption, and might help the AEC designers in China to build confidence in BIM adoption.

4.1 Schematic Design Phase

The perfect timing for Positive BIM Technology interaction is from the scheme design phase. It's the real-time collaboration of the data and the 3D volume, reasonable site plan based on building

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simulation analysis, colored floor plans using specific strategy, and the scheme-related data tables that power the work efficiency most in this stage. Work that used to take days now can get done in minutes.

Figure 15 lists the 4 steps for massing study and real-time data generation. Through the establishment of mass by Revit and setting the elevation, the mass floor can automatically form. The massing study process is way faster with the real-time floor area schedule.

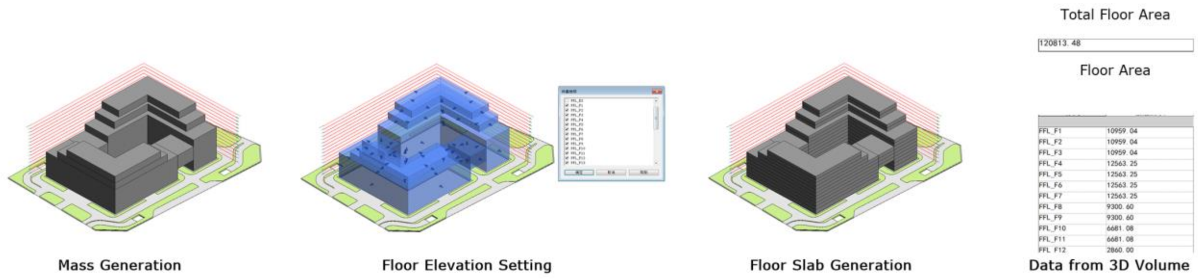

Figure 15: Massing study and real-time data generation.

Moreover, one of the significant benefits of BIM is the ability to effectively use analysis and evaluation programs during design, as feedback [1]. The massing model can be developed into a reasonable schematic model by the building simulation analysis. Figure 16 illustrates this workflow, and Figure 17 gives an output example of a building simulation on incident radiation.

Figure 16: Workflow of massing model to schematic model with building simulation.

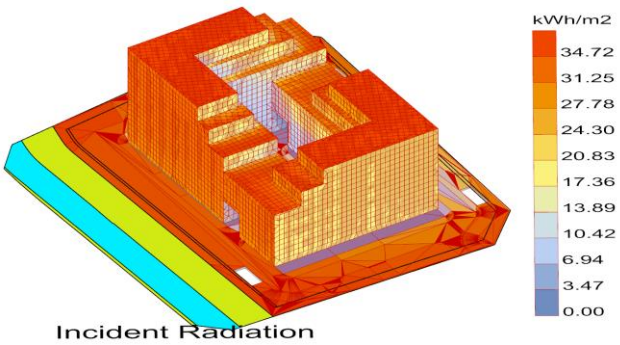

Figure 17: Building simulation on incident radiation by Ladybug & Honeybee python script.

The color schemes for floor plans and area schedules in different filter logic (level, programming, etc.) or data organization strategies (room name, level, etc.) are quickly editable. It provides high efficiency in statistical data and mathematical analysis. Figure 18 is a colored floor plan based on customized color scheme settings. The colored floor plans for different uses can generate within minutes based on the matched color schemes. Figure 19 is the floor area schedule. It organizes

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well in logical priorities: floor level, program, and room name; it also calculates the area ratio for each room and each program.

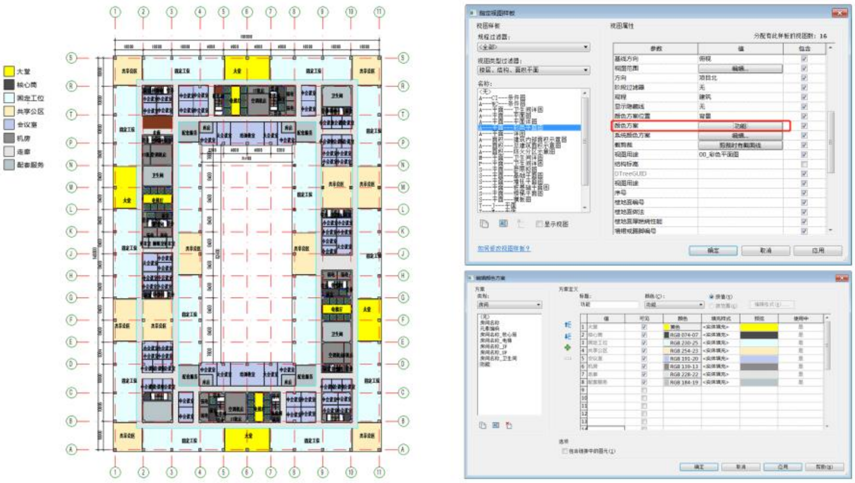

Figure 18: Colored floor plan generation and its color scheme setting.

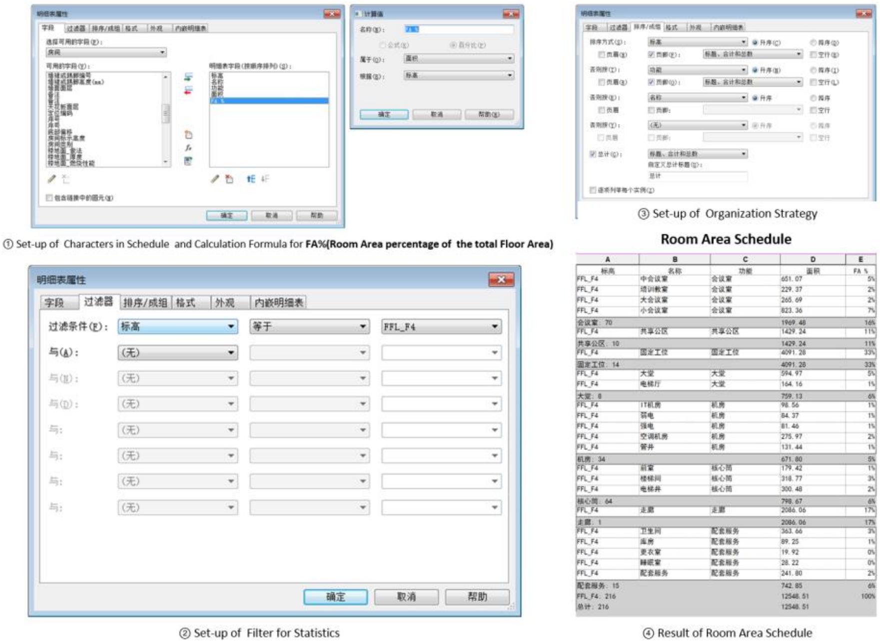

Figure 19: Editable filter, data organization strategy, and mathematical analysis of area schedules.

4.2 Design Development Phase

The most efficient timing for BIM Technology application is the design development phase. During this stage, easy understanding and quick coordination for the project between architects, structural engineers, and MEP engineers can get realized by BIM. Communication cost has been

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minimized since all the components exist in the 3D model. System collision or other problems can get exposed in the early stage of the design phase, and it avoids the possibility of the project's fundamental changes in the construction document phase. Optimized flow of information is considered necessary so as to achieve high-performing buildings where decision-making is based on the latest version of information [3]. Figure 20 shows the collaborative work between architects and structure engineers. The design management system enables the architectural drawings and structural drawings to exist in the same 3D model file. Each team member has immediate updates once any change happens in the design. Without BIM, those tasks are usually defined based on 2D AutoCAD drawings, requiring a great deal of understanding of the drawings, the correct overlapping of drawings in order to detect conflicts and a huge attention in the verification of the correctness of target design updates [11].

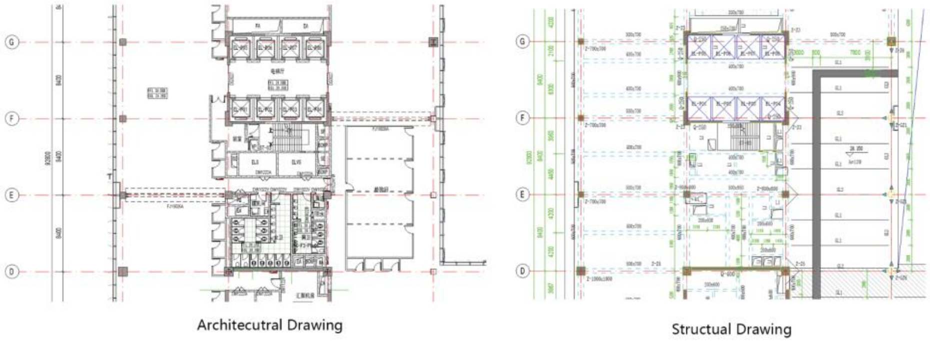

Figure 20: Architectural and structural drawings in the same BIM file.

Besides, the data can be extracted from the model and worked out to generate information that can support several analyses in order to make decisions and to improve the process of delivering the facility [11]. For example, the building code analysis, which needs a lot of time and might meet possible omissions in the AutoCAD era, can be done automatically with the help of the algorithm. Figure 21 exhibits the process of automatic egress circulation generation tagged with Ped-sim (pedestrian simulation) data of egress distance and time needed, which is Dynamo scripted.

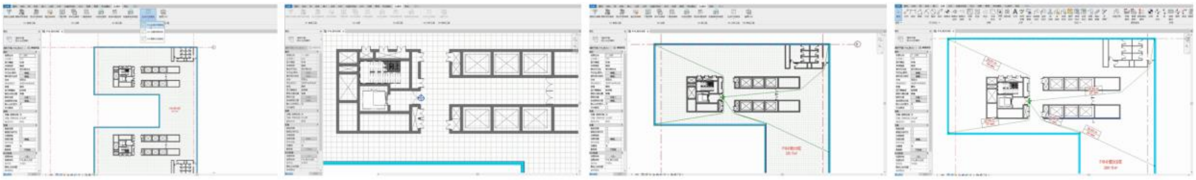

Figure 21: Automatic egress circulation generation by Dynamo: (a) Choose the egress circulation generation function, (b) Locate the exit, (c) Egress circulation automatically generated, and (d) Tag the distance and time needed to escape.

4.3 Construction Document Phase

It's time for the design team to get paid back and make significant profits in the construction document phase, only with the Positive BIM Technology adopted in the design development phase. As mentioned in Figure 6, the BIM project saves nearly three months in this stage compared to the AutoCAD project. One reason is that most design issues have already been solved due to the BIM adoption in the design development phase. The design floor plans are relatively stable, and the BIM model keeps developing, from LOD 200 to LOD 300 (Figure 22).

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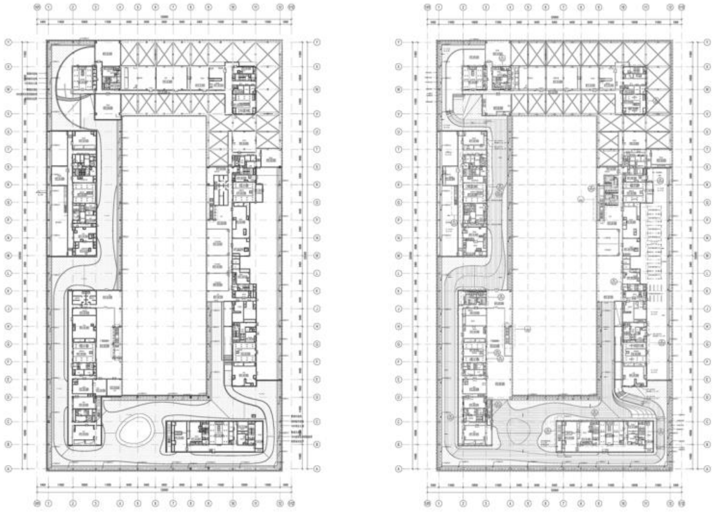

Figure 22: BIM model development: (a) LOD 200 in design development phase, and (b) LOD 300 in construction document phase.

The other reason is the advantage of the script-friendly feature in BIM. The images below show two algorithm applications in Revit. Figure 23 is the result of automatic dimension annotations (in blue color) by Dynamo and Python. With this secondary development application, dimension annotation can automatically appear following the definition of the boundary and the direction. This application can automatically recognize the door, the wall, the window, and any other components for measurements, due to the clear family classes for each component. Figure 24 is the algorithm process of automatic view sheets creation from views by Excel data and C# coding. Excel is an efficient tool for parameters management by listing views' names as the source, view sheets' names and sheets' numbers as the targets, and drawings' names and locations on each view sheet as the output. In the C# coding, the view sheets can be created with parameters of the view sheets names and the sheets' numbers, and the views can be added to view sheets with parameters of view sheets names and location. Thus, view sheets with drawings are automatically generated and organized. The dimension annotation and sheets organization work usually took days, even weeks, in the AutoCAD era. However, with the help of the script, this kind of work can be done in one day, or just a few hours. Thanks to the one-to-one correspondence between data and geometry, the power of BIM removes lots of tedious burdens from the design team.

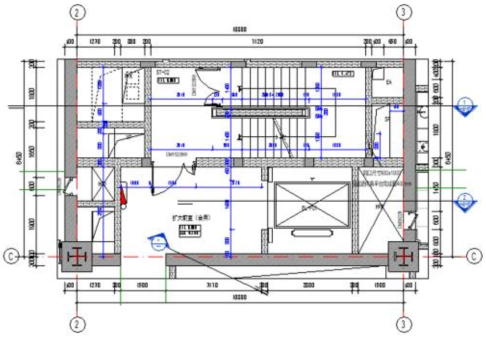

Figure 23: Detail drawing of staircase with automatic annotation generation.

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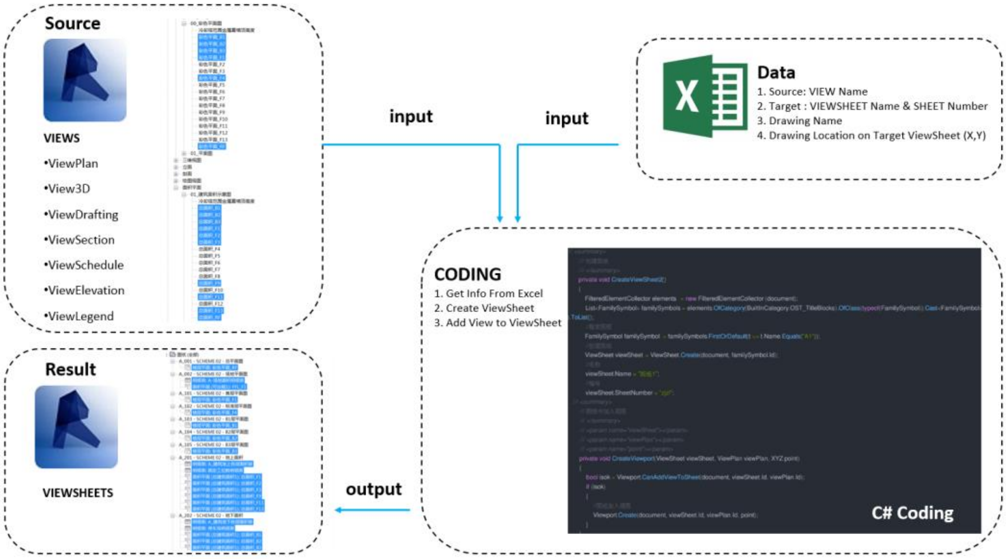

Figure 24: Revit View sheets created from Views with coding.

Additionally, the BIM cloud platform is a superb tool for quick discussions on design details in this stage. It's much easier for cloud collaboration on a laptop or smartphone by simplifying the BIM model. Figure 25 gives an example of the BIM cloud platform application for easy measurement and convenient discussion among the client, designer, and project manager. The service "Cloud BIM" would create the use of multiple nD actions asynchronously, such as 3D (three dimensional modeling), 4D (time - programming), 5D (costing) and 6D (sustainability) [2].

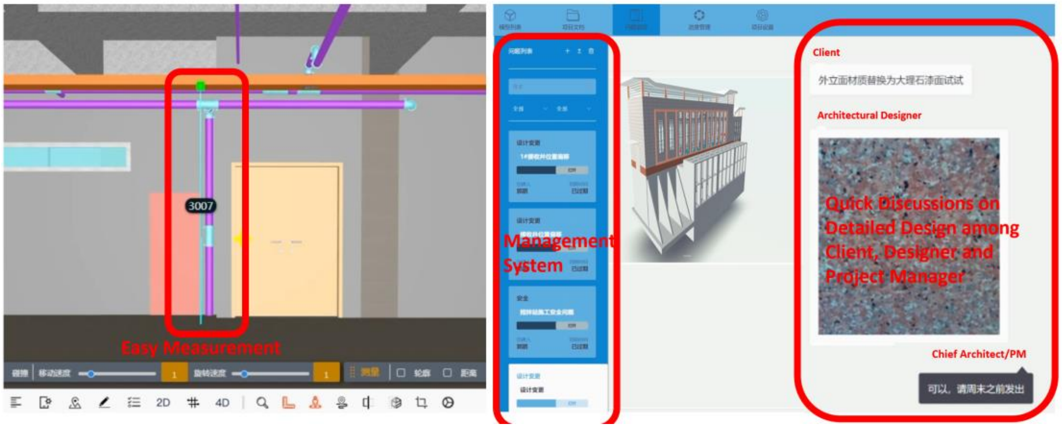

Figure 25: BIM cloud platform: (a) Easy measurement, and (b) Convenient communication among the client, designer and project manager.

5 CONCLUSION

BIM Technology has overriding advantages during the project's whole process, and it significantly improves the work efficiency in the AEC industry. But its popularization in China is greatly limited,

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especially in design companies. To change this situation, the design companies, the design teams, and many other members of the whole industry should make considerable efforts. The design teams, a leading position in this process, cannot simply rely on the outsource BIM model firms to do "BIM Model Translation". Instead, design teams must take a positive part in the BIM implementation, and contribute to its popularization. Positive BIM Technology mainly aims at the design phase, from schematic design to the construction document phase. Its value relies not only on the typical collision check among different systems or collaborative design but also on the establishment of a robust industrial chain in the AEC field by smooth information delivery. Its adoption will accelerate the process of the AEC industry informatization. What's even more exciting is that Positive BIM Technology could also provide unlimited opportunities for the connection with the IT industry, and make full preparation for Industry 4.0. Every small step of each practitioner together will make a big difference for the whole industry. Hopefully, BIM implementation level will be 100% in one day. That is the time for the AEC field to realize its informatization.

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