# Technological Changes
# Brought by BIM to Façade Design

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# I. Foreword

With the continuous progress of building industry technologies and people’s constant pursuit of sustainable buildings, Building Information Modeling (BIM) has been a new subject heatedly discussed and explored in the building industry. Thanks to its advantages of visualization, coordination, simulation, optimization, and drawing-creation, BIM has sparked great changes in engineering construction, and is becoming widely popular in Asian countries. Countries including the U.S., the U.K., Singapore, South Korea, and Japan have issued BIM guidance standards for the application and development of BIM in their countries. BIM has played a huge role in the construction of many complex projects, such as Shanghai Tower (the world’s second-tallest building with a height of 632 meters), Shanghai Disney Resort (winning the U.S. AIA 2014 award for BIM application), and Tokyo Sky Tree (the world’s tallest tower at 634 meters).

Architectural envelopes are the coat of a building, organically integrating building aesthetics, building function, building energy efficiency, building structure, and other factors. Today, as architectural envelopes of different materials and in different structural forms have been seen all over the world, architectural envelopes are synonymous with grandeur, elegance, and modernity, and become an important symbol and outstanding feature of a modern metropolis.

Although central to the building industry, façade fabrication has roots in the machine manufacturing industry, and is the most cross-disciplinary branch in the building industry. In design, manufacturing, and installation, the architect’s tireless artistic pursuit and the continuing emergence of urban complexes and super high-rise buildings give façade design technology plenty of space to play its role, and the advent of BIM brings good opportunities for the development of façade design engineering. This paper will mainly analyze the application of BIM in façade design, discuss the advantages and challenges of BIM, and give the prospects for the technological changes brought by BIM to the whole industrial chain of façade design, fabrication, and installation.

# II. Overview of architectural envelopes industry development

## 1. Current situation and prospects

The first building introduced with an architectural envelope was the Crystal Palace in the Great Exhibition held in London in 1851 (see Figure 1). For the exhibition hall for most exhibits, a greenhouse-like frame glass structure was adopted, which not only rendered the Crystal Palace the most glorious of all exhibits, but also pioneered façade design engineering.

**Figure 1.** The Crystal Palace in the Great Exhibition held in London in 1851. Appearance of Crystal Palace (left), Interior (right)

After nearly a century of development, façade fabrication, in terms of type, has developed from simple exposed-frame glass to semi-exposed-frame or hidden-frame, with full-glass, as well as using various metal, stone, or artificial panels. In terms of structure, façade fabrication has developed from a simple frame to a unitized, point-supported, double-skinned, membrane.. In addition, more energy-efficient, ecological façade panels, photoelectric façades, and intelligent façades are gathering momentum. Obviously, façade design technology is advancing rapidly. It helps architects free their minds and enables façade design to develop from being simple and monotonous to diversified, complex, and modern.

The architectural envelopes market is mainly driven by the development of the global economy and building industry. Global economic growth promotes investment in fixed assets, and the construction demands of all kinds of public facilities, commercial buildings, and high-end residential buildings provide a foundation for the growth of global architectural envelopes markets. From the distribution of the market, it can be seen that the U.S. and Europe are still the dominant players, with a combined market share accounting for about 50 percent in 2009. In the meantime, the emerging countries represented by

China and India are enjoying rapid growth of their architectural envelopes industry (see Figure 2). According to related statistics, China is the country with the most super high-rise buildings being-constructed and planned in the world. The number of buildings in the country above 200 meters tall accounts for 48.5 percent of the total number of the buildings in the world. A large number of projects to be started in the future will demand much from the architectural envelopes industry.

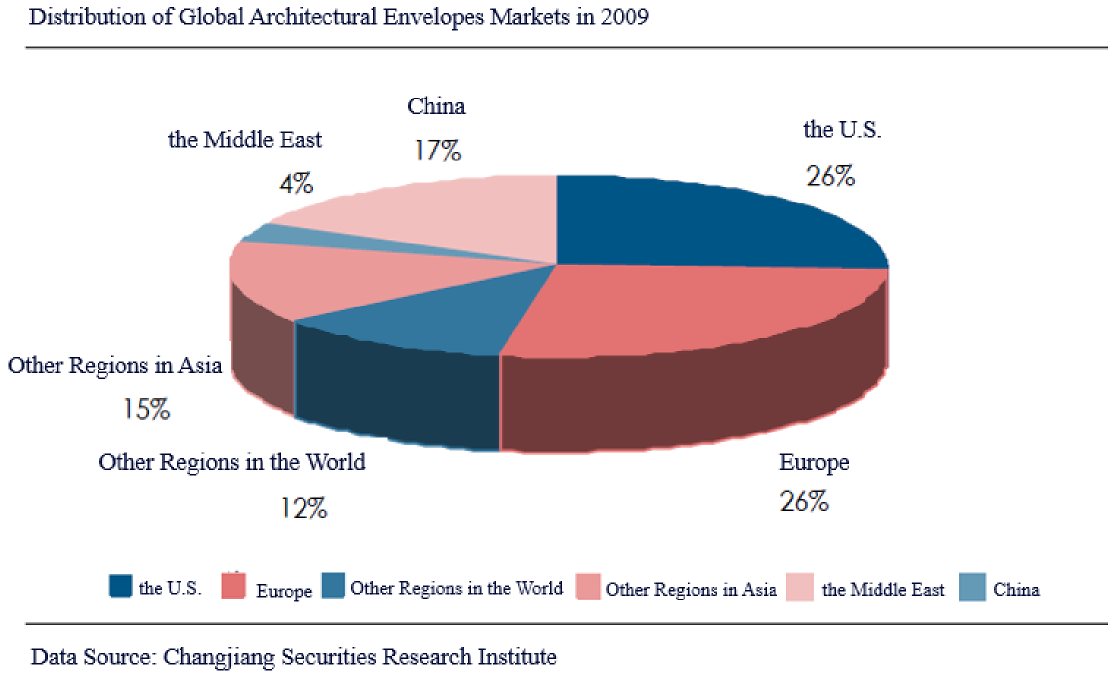



**Figure 2**. Distribution of Global Architectural Envelopes Markets in 2009

It can be predicted that in the future, the U.S. and Europe will still take the lead in the design and application of architectural envelope products, and the developing countries of Asia (especially China), the Middle East, and other regions will be the main battlefield and driver of new products and application demands of architectural envelopes globally.

## 2. Analysis of challenges in industry development

The traditional building industry suffers serious productivity waste because of poor utilization of building materials, engineering rework, idling of labor, etc. According to related statistics, the value of the resources wasted in construction for a project accounts for as much as 25 percent of the total investment, largely wasted in façade design, fabrication, and installation. For sustainable and healthy development of the architectural envelopes industry, it is required to analyze the reasons for the waste from the perspective of the full lifecycle of a façade fabrication, examine the challenges arising in the development of the architectural envelope industry, and grasp the opportunities of industry development.

### Challenge of project management mode

Façade design (especially for complex curtain walls) is a highly professional engineering task requiring a distinguished appearance, technical functionality, and significant investment in installation planning. So, like structural design, plumbing design, and electrical design, façade design requires special expertise. Typically architects designing façades try to avoid a single manufacturer's product so that the contractor can bid alternatives. This means that the architectural drawings are not coordinated with shop drawings from a manufacturer until construction has started and by that time much expert knowledge has been missed with several potential consequences: 1) the final design deliverables fail to embody the progress of façade technology and new products; and 2) the design scheme cannot meet the building energy performance requirements in an economical way.

For close coordination between façade design and main building design, an independent third party as façade design consultants is important. At the building schematic phase, the architects ask the façade design consultants for advice on their schematic design, so as to make possible the best building appearance; at the design development phase, the façade design consultants determine the system to-be-adopted, reserved room, etc. for the architectural envelope to provide more refined façade design drawings for façade contractors bidding. The façade consultants should be able to produce a 3D model that incorporates the architect's construction and fabrication drawings.

### Data disconnect from design to manufacturing

Compared with the traditional building industry, façade design engineering is mostly based on custom manufacturing in plants. It is an industry formed from the close combination of building and industrial manufacturing. It is hoped that the accurate 3D model and 2D CAD drawings of a complex façade model can be completely sent to the numerical control cutting machines in plants. However, due to lack of relevant cross-industry standard criteria, the data chain from façade design to manufacturing breaks, resulting in poor collaboration in problem solving, which seriously affects the industrialization of the architectural envelope industry. When an architect changes 3D models, the façade designer has to redevelop the detailed façade design and generate new fabrication drawings independently, thus causing a huge waste due to delay and rework.

**Production and installation requirements of a complex architectural envelopes**

Compared with traditional manufacturing, a façade panel has a higher degree of customization, which is reflected by not only different designs for different projects, but also different façade panels even in a single project, so fast and flexible production is required as needed. With the emergence of new materials and new technologies, and people's constant pursuit of different building appearances, façade fabrication becomes bigger and bigger in size and increasingly complex in shape, accompanied by increasing difficulties in field installation. If the delivery sequence and installation process are not well managed, the installation positions of façade panels may be confused, thus causing project delay and the waste of resources. It is a pity that seamless connection of data for detailed façade design drawing, detailed joint fabrication technology, and field installation positioning (as well as realization of drawing-less and model-driven fabrication design which is a concept advocated in the machinery industry) is now beyond the capability of most BIM tools. What we need is an accurate data integration environment incorporating building design, detailed joint design, and field installation together covering a series of management activities, including façade fabrication production, positioning, detection, cost estimation, and risk control.

## III. Changes brought by BIM to façade design

### 1. Impetus from information technology to façade design

To meet the requirements for energy-efficient, green, and sustainable buildings, and to respond to the increasingly serious shortage of contractors and the resulting increase of cost, industrialization of façade design engineering is one of the development trends of the architectural envelope industry. Industrialization of façade design engineering must be promoted by the industry and, in turn, its improvement can boost promotion.

## CAD and VR

Since the birth of computer-aided design (CAD) in the last century, engineers have abandoned manual drawing and turned to electronic drawing. This has changed traditional design methods and brought the first revolution in the façade design engineering field. To manage CAD data, information technology also underwent a three-stage evolution from CAD file management, to CAD database management, to product data management (PDM). PDM is an integrated working mode that can provide a façade design collaboration environment for sharing, so that designers can work on the same database, reducing unnecessary transfer and confirmation and fully sharing information resources.

The rapid development of three-dimensional modeling and virtual reality (VR) technology helps improve communication efficiency among the multiple parties involved in façade design. The visual expression of a three-dimensional model can help architects and façade designers freely exchange ideas and deliberate on the designed volume, shape, façade, and exterior space throughout the design, but the aforesaid façade surface model cannot hold more design information for construction and installation. In addition to the physical dimensions of the architectural envelope and required materials, design information also includes wind pressure resistant strength, seismic resistance, air tightness, water tightness, transformation, construction technology, heat transfer coefficient, etc. Indetermination of such information will lead to poor efficiency in subsequent work, such as building estimate and budget, fabrication, field installation, etc.

## VDC and BIM

Industry demands promote the continuous integration of three-dimensional geometry-based modeling technology, VR technology, and BIM technology, and development toward integrated application. Virtual design and construction (VDC) is another concept becoming popular in the engineering construction industry. It requires, through the multidisciplinary parametric models provided by design, construction, operation, and maintenance teams in project construction, integration of building facility information, the construction process, and the management organization to ensure the achievement of general management objectives for the project. If the VDC management concept can be implemented, we will be able to capture and reuse data from conceptual design to prefabrication and even in downstream processes, and apply the data to the entire process from concept design, to modular construction, to component prefabrication. Then, we will have the chance for “building industrialization”.

BIM is one of the core technologies to implement VDC. BIM technology is highly correlated with industrialization of façade design engineering logically. Based on BIM, the carrier of building information, not only the visual design, multidisciplinary integration correction, panel optimization analysis, and quantity calculation for the architectural envelope, can be possible. A breakthrough can be made, specifically, the mode of documentation in design delivery in the traditional building industry which serves no one well. Instead, the panel fabrication drawing can be directly generated and the component fabrication data can be directly extracted from the design model, which makes possible the paperless design and plant fabrication of the curtain wall unit. BIM technology has become the inevitable choice for industrialized development of the architectural envelope industry.

## 2. BIM-based façade design features

### Parametric design

BIM-parametric design changes all the elements of a façade fabrication to a functional variable, and then, by changing the function, or to say, by changing the algorithm, drives the façade panel shape to change, thus creating different building design schemes.

As an art of building, façade design fundamentally has an anti-logic basis. As aesthetic theory goes, there is no debate for taste. Sticking to conventional thoughts will never lead to the palace of art. However, parametric design is not contradictory to traditional building design. It is oriented to the future, and has many unimaginable forms. It is a tool that can inspire designers.

In-BIM parametric design (see Figure 3), all real attributes of façade fabrication components are given a parametric simulation and calculation, as well as related data statistics. In BIM-parametric design, a façade component is not only a virtual geometric component, but also has other geometric attributes, such as component material, thermal performance, cost, as well as purchase information, weight, installation number, etc. The significance of BIM-parametric design is that we can, according to different design parameters, quickly conduct calculations and statistical analyses on modeling, layout, energy conservation, evacuation, etc. and then give priority to the most appropriate scheme. This is where BIM-parametric design differs from ordinary parametric design that is only for the geometric modeling.

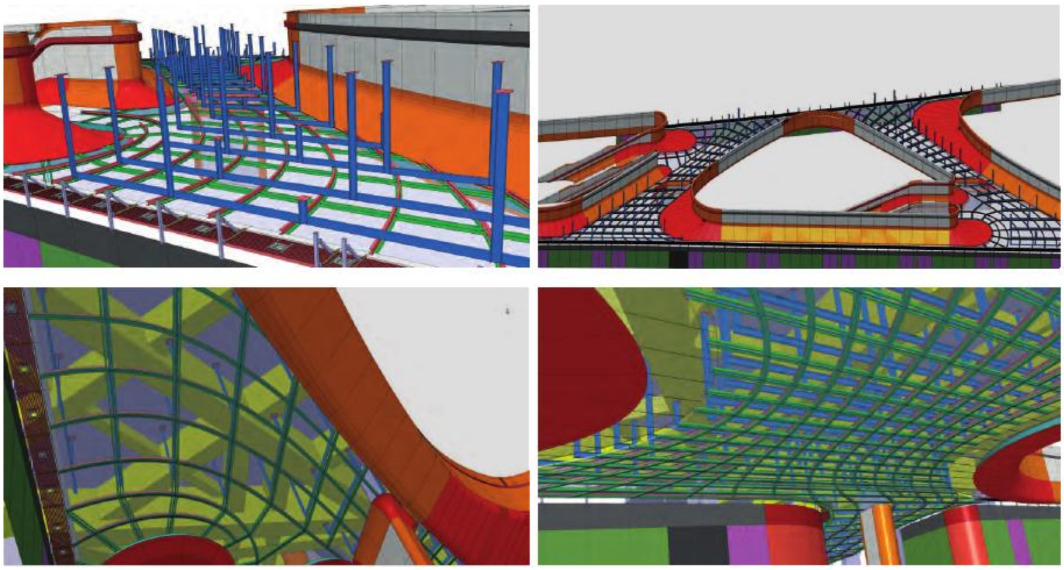


**Figure 3**. SKY SOHU Project BIM models [2]

It is noteworthy that the concept of parameterization is different from the concept of parametric design. Parameterization refers to the modeling capability of BIM software, which is an important guarantee for realization of parametric design. BIM software applicable to façade design must, first of all, provide "accurate" BIM capability to ensure that the modeling accuracy of small BIM components, such as round hole, bent piece, etc., is within the allowable plant fabrication error range. The American Institute of Architects (AIA) uses level of detail (LOD) to define the accuracy of building components in BIM. According to LOD, BIM evolves from an approximate model to an accurate completed model through the progress of a project, and the model accuracy is from the rough to the subtle:

- LOD100—Conceptual
- LOD 200—Approximate Geometry (scheme and enlarged preliminary)
- LOD 300—Precise Geometry (construction drawing and detailed construction drawing)
- LOD400—Fabrication
- LOD 500—As-built

For an ordinary building design, when the model accuracy is within LOD100 to LOD300, the design delivery can be completed; but for a façade design, to ensure the design delivery model can be applied in subsequent plant fabrication, the modeling capability of the BIM software must reach LOD400.

### Knowledge-based visual design

A BIM-based three-dimensional virtual design environment helps quickly transfer design information and simulated information to project partners, so as to improve their communication efficiency, make possible WYSIWYG (what you see is what you get), and reduce economic losses caused by redesign. Visualization can be used for design clarification of detail structure joints, such as the façade panel edge, corner, hole, junction, and beam bottom flashing and trim. Besides, visual display can help quickly discover any conflicts among disciplines and improve design quality.

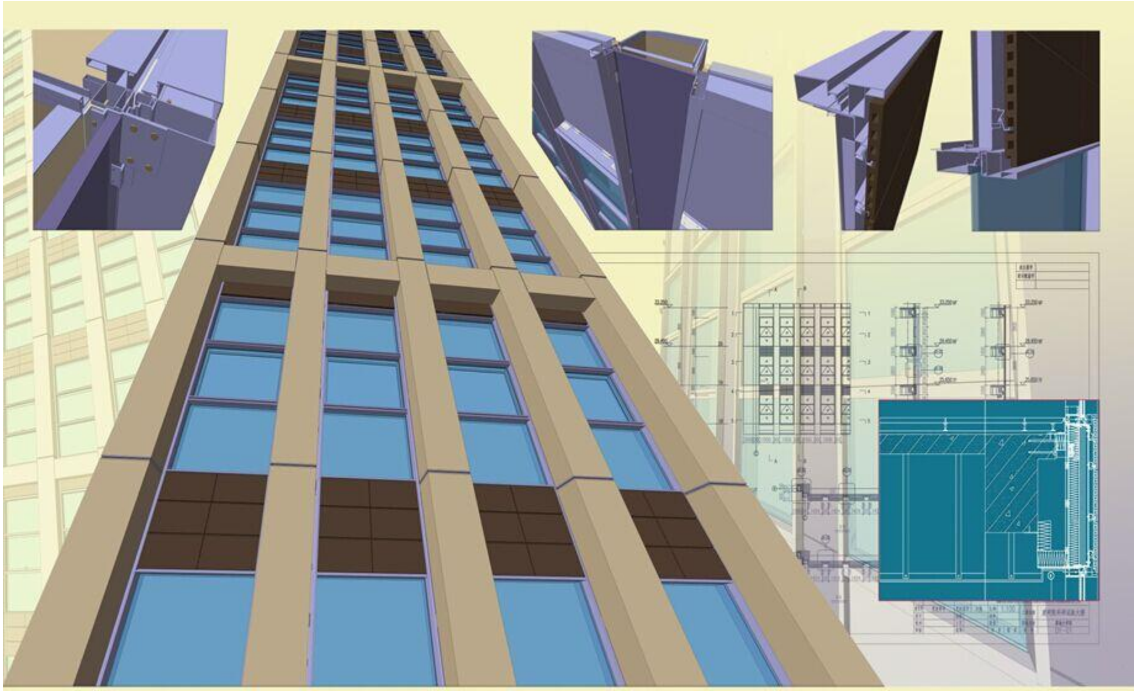


**Figure 4**: Curtain Wall Joints of CABR Research Building (Source: CABRTECH BIM Team)

BIM visualization is automatically generated using the information for entity components. We can have the multi-view sectional drawings and axonometric drawings of a curtain wall model automatically generated to transfer information (see Figure 4). There are correlative and feedback relations among the components in such a “tridimensional wall”. When a façade design engineer modifies a component, all the views in relation to the component will be automatically updated, saving us the trouble of modifying the plan, elevation, and section respectively. The “correlative” visual feature is conducive to improving communication efficiency and also improving design engineer work efficiency, solving the long-standing problem of discrepancies among, omissions in, and incompletion of drawings.

### “Top-down” design

From concept design, to modeling design detailing, to plant fabrication, to the final installation, the curtain wall is involved in many steps and covers both building and mechanical fabrication fields. In most cases, data cannot be smoothly connected, and data chain breaking may occur. Based on data chain inheritability underlined by detailed BIM design, and with BIM as carrier, the “top-down” design idea can help accurately get the upstream curved-surface modeling data and also accurately coordinate fabrication.

For “top-down” BIM design, it is required to first construct a “top basic skeleton” of the design, and then make copies, modifications, and detailing based on this “top basic skeleton” in the subsequent design process, finally completing the detailed design. For example, the entire façade design engineering of a project is the highest-level “top basic skeleton”. The tower, floor, and other parts can be broken down into several levels of “top basic skeleton” and each can show the geometric shape and spatial position of the façade panels in the part and reflect the geometric constraint relation with other “top basic skeletons”. Thus, the “top basic skeleton” is the core of the detailed “top-down” façade design development, and also the bridge and link for the interrelation among façade panel components.

The parametric modeling capability of BIM software is the basis for the smooth development of detailed “top-down” design. In BIM-based parametric modelling, design can be automatically modified by parameter driving. There is an obvious corresponding relation and global correlation between the parameters and the controlled sizes of the model, so that the transfer of model data changes from and to different levels enjoys uniqueness and instantaneity. The “top-down” BIM design has several characteristics:

The geometric modeling of the façade fabrications can be easily transformed into building components with real attributes. When we change parameters to make a geometric shape change, building components change accordingly, which relates visual shape to real façade fabrication components, so that the visual model is transformed to a real “information model”. In the detailed design of a metal curtain wall, for instance, BIM-base technology can help, according to the architect’s requirements, generate a large complex curved surface, easily divide the curved surface, and cut the shape into small, simple-technology, material-saving curved panels suitable for mass production. Then, via sheet metal unfolding, turn them into drawings of plan view size, and make perform cutting and blanking with fewer errors or error free. Furthermore, using the building components with real attributes, an enterprise can gradually enrich and complete its parametric curtain wall component library, conducive to accumulation and reuse of enterprise knowledge.

**Table 1**: Sample Bill of Quantities Extracted From Façade BIM Models [2]

| BUILDING ENDS CLADDING | TOTAL AREA | FLAT | | SINGLE CURVED | | DOUBLE CURVED | |
|---|---|---|---|---|---|---|---|
| | m2 | m2 | % | m2 | % | m2 | % |
| LOUVERS | 2603.15 | 836.43 | 32.13 | 1766.72 | 67.87 | 0.00 | 0.00 |
| RIBBON | 429.43 | 42.28 | 9.85 | 298.96 | 69.62 | 88.19 | 20.54 |
| SOLID AREA TOP | 248.85 | 149.89 | 60.23 | 98.96 | 39.77 | 0.00 | 0.00 |
| SOLID AREA BOTTOM | 271.42 | 124.09 | 45.72 | 79.40 | 29.25 | 67.93 | 25.03 |
| INTERNAL RIBBON | 53.60 | 38.14 | 71.16 | 15.46 | 28.84 | 0.00 | 0.00 |
| INTERNAL RIBBON BALCONY | 531.24 | 0.00 | 0.00 | 189.17 | 35.61 | 342.07 | 64.39 |
| TOTAL AREA (PER TIP) | 4137.69 | 1190.83 | 28.78 | 2448.67 | 59.18 | 498.19 | 12.04 |
| TOTAL AREA (x8 TIPS) | 33101.52 | 9526.64 | 28.78 | 19589.36 | 59.18 | 3985.52 | 12.04 |

| RIBBON CLADDING | TOTAL AREA | FLAT | | SINGLE CURVED | | DOUBLE CURVED | |
|---|---|---|---|---|---|---|---|
| | m2 | m2 | % | m2 | % | m2 | % |
| RIBBON BUILDING ENDS | 869.61 | 26.24 | 3.02 | 420.34 | 48.34 | 423.03 | 48.65 |
| RIBBON LONG FAÇADE | 14756.00 | 274.23 | 1.86 | 14317.66 | 97.03 | 164.11 | 1.11 |
| RIBBON BRIDGES | 6026.95 | 960.73 | 15.94 | 4540.36 | 75.33 | 525.86 | 8.73 |
| LOUVERS 80% PERFORATION | 16.17 | 16.17 | 100.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| TOTAL AREA | 21668.73 | 1277.37 | 5.89 | 19278.36 | 88.97 | 1113.00 | 5.14 |

| ROOF POP-UPS CLADDING | TOTAL AREA | FLAT | | SINGLE CURVED | | DOUBLE CURVED | |
|---|---|---|---|---|---|---|---|
| | m2 | m2 | % | m2 | % | m2 | % |
| SOLID PANELS | 2646.20 | 2469.74 | 93.33 | 176.46 | 6.67 | 0.00 | 0.00 |
| DOOR PANELS | 95.33 | 95.33 | 100.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| PERFORATED PANELS | 815.26 | 815.26 | 100.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| TOTAL AREA | 3556.79 | 3380.33 | 95.04 | 176.46 | 4.96 | 0.00 | 0.00 |

After the shapes and positions of “top basic skeleton” are satisfactory, optimizing special-shaped curved panels can be done to meet the requirements of complex surfaces for fabrication, transportation, installation, and cost. The façade designer modifies the shapes of curved panels by parameter driving, and, within the allowable visual error range, replaces double-curved surfaces with single-curved surfaces, and curved surfaces with flat surfaces to generate a standard, simple façade fabrication wherever possible. In the meantime, the façade designer must give consideration to cost, construction difficulty, physical performance, and nice appearance. For instance, the façade designer must take into consideration the supply situation for panels and the fabrication parameters of numerical control machine tools, and calculate the maximum sizes of panels, for purposes of gradual optimization and balance between nice look and cost efficiency.

The reason why BIM software can enable panel optimization lies in its excellent parametric modeling capability and its real-time data extraction capability (see Table 1). Because the façade model contains geometric information (about panels, keels, connecting pieces, supports, and embedded parts), material information, and management information, when the façade panel shape changes, the corresponding material list and cost information is generated quickly. Because the cost of a special-shaped, curved-surface façade panel is uncertain, the adjustment of the curtain wall shape will definitely change a series of factors, including component cost and fabrication requirements. BIM can correlate all the factors to form a data model with a dynamic update function, which is used to continuously improve and optimize the previous curved-surface façade models, compare the cost indicators for different design schemes in real time according to the output tabular bills of quantities, and, through a step-by-step iterative loop, finally make possible the balance between nice look and cost efficiency.

**Automatic professional correction**

As façade design engineering becomes more and more complex, there is a trend of cross-disciplinary cooperation in façade design. When the main structure is nearly completed, façade engineering can start, together with electromechanical engineering. Façade design is closely related to other disciplines in terms of spatial position. BIM can change the traditional mode-of-work coordination among architects, structural engineers, and façade design engineers, and integrate the BIM models of different disciplines for interdisciplinary collision detection to discover if the geometric position conflicts among different disciplines in advance. For instance, through interdisciplinary collision detection, we can determine:

- the reserved room between curtain wall keel and concrete structure
- whether the structure leaves adequate room to the façade fabrication
- whether the positions of embedded parts are accurate
- whether there are any conflicts with decor and electromechanical positions

In another instance, we can examine whether the positions of large trimmings and logos are matched with the façade fabrication structure to determine whether there are any conflicts between the building and the façade fabrication.

## 3. Changes brought by BIM-based design to subsequent processes

**Model-based design delivery**

Model-based design delivery is one of the important means of industrialization of the architectural envelope industry. As façade fabrication is mostly customized in plants, design and fabrication are closely combined. Compared with traditional manufacturing, façade panel units enjoy a higher degree of customization, which is reflected by not only different designs for different projects but also different façade panels even in a project, so fast and flexible production is needed. Apparently, mass production based on standardization and regularization of façade panel units is not the mainstream direction of industrialization of façade design engineering. But, BIM-based design delivery can help avoid information loss during the transformation of two-dimensional design to three-dimensional fabrication model, and accurately transfer the façade design data to the numerical control machine tools, directly used for façade fabrication. Therefore, the complete, accurate transfer of design data and automatic digital fabrication can not only improve building quality, but also reduce the huge waste arising from the design to different fabrication steps, which may be the industrialization development trend of the future architectural envelop industry.

### Virtual assembly

Recently, unitized façade fabrication is increasingly being applied. Because unitized façade panels are fabricated and assembled in workshops, the builders working at the construction site must have a good knowledge of the façade panels for different façades and of different floor heights and types, so as to have them correspond to the right positions. After the detailed BIM-based façade design is completed, the components, such as unit panels, keel frames, and irregular profiles, can be given unique codes according to data planning; then the façade model of the whole building is assembled, and the data can be extracted to generate a material list. In the material list, each component has a unique number (see Figure 5). Blanking, fabrication, and management of material placement are done according to the numbers and the units are quickly assembled according to the standard unit template drawings.

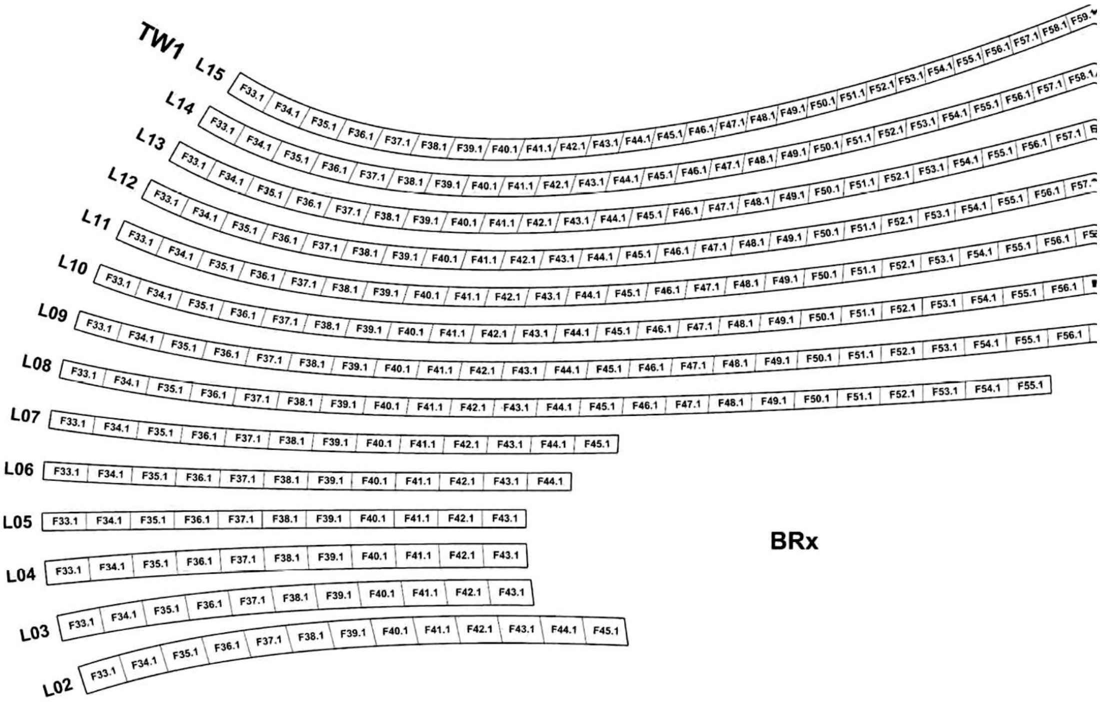



**Figure 5**. The Installation Number of Façade Panels Generated From the BIM Models of GALAXY SOHO Project [2]

It is required to note the information about fabrication, transportation, and installation direction and sequence in the façade panels. BIM capabilities can then easily be employed to preassemble the façade panel to better arrange the multi-operational construction plan and installation sequence, scientifically create site planning, reasonably arrange the construction period, improve installation quality, and reduce the idling of the labor force.

# IV. Examples of application of BIM to façade design

## Phoenix International Media Center

Phoenix International Media Center, located at the southwest corner of Beijing Chaoyang Park, with gross floor area of 65,000 square meters and building height of 55 meters, was designed by Beijing Institute of Architectural Design. The overall design logic is to wrap the main, independently-maintainable space with an ecologically-functional shell, rendering a building-in-building form. There is some interesting shared and public space in between, so as to meet the purpose of public involvement and experience and environmental protection. In addition to media office and studio production facilities, there is also lots of interactive experience space open to the public, so as to reflect the unique open business concept of Phoenix Media. To show the uniqueness, culture, and rationality of technology and cost, the architects creatively proposed for the outer surface of the center a flake-type, unit-combined façade fabrication of which no two of the 5,180 units are the same  (see Figure 6).

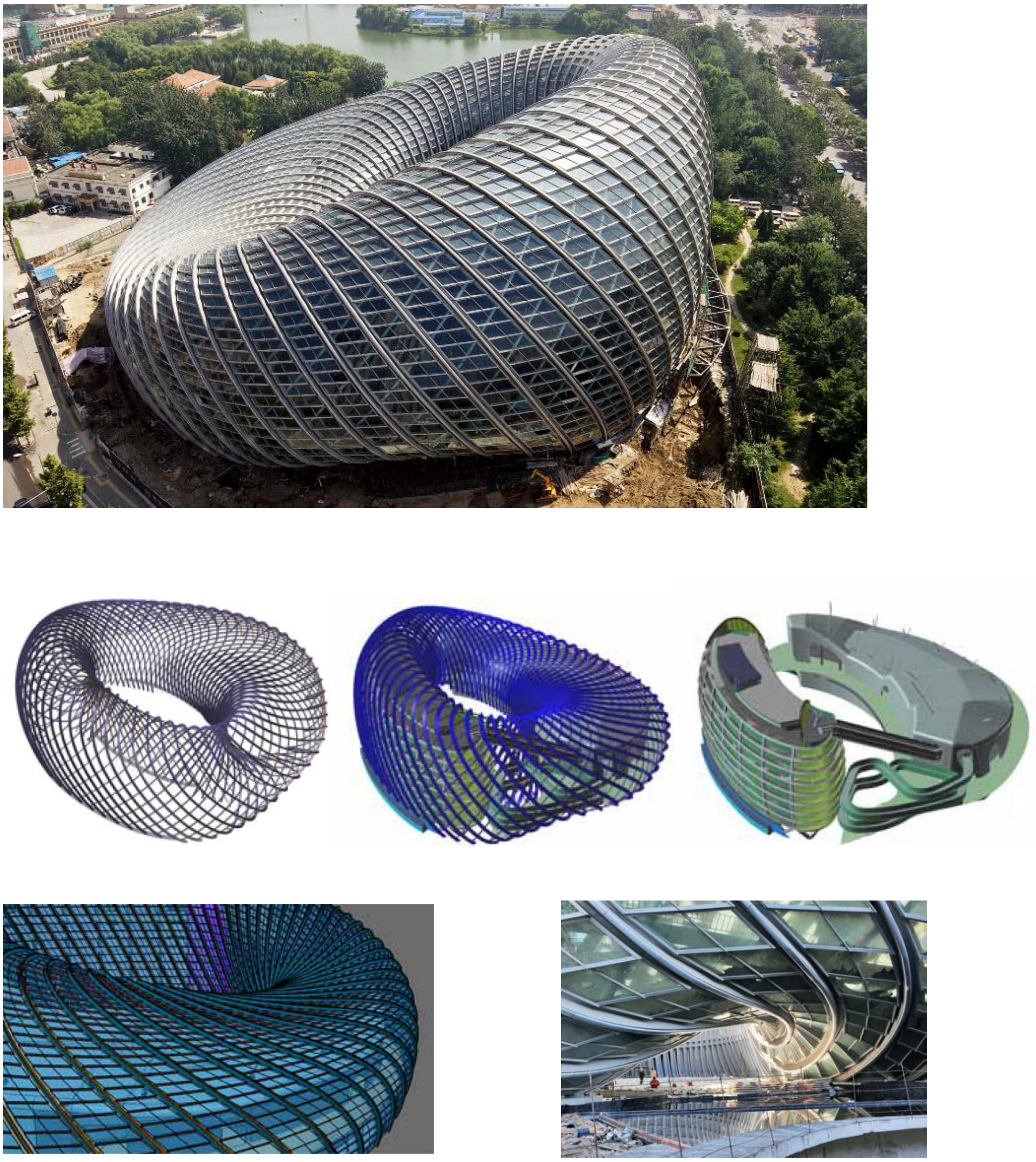
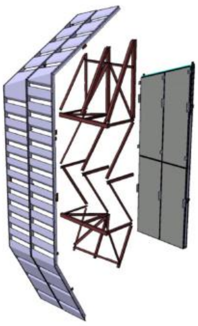
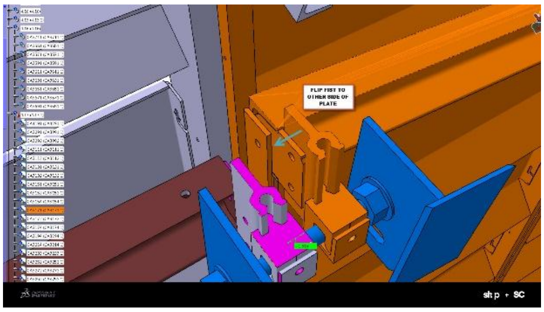


**Figure 6**: Phoenix International Media Center [3, 4]

## Barclays Center

Barclays Center, covering an area 675,000 feet, designed by SHoP Architects, reflects the balance between unique shape and good performance. Its complex, weather-resistant steel and glass façade design, a main part of arena design, was fulfilled by SHoP Construction (SC) cooperating with a façade contractor. To ensure the “grille” division of the weather-resistant steel can accurately show the building shape, SC introduced an integrated construction process directly oriented to assembly and applied digital fabrication technology to assemble and deliver 900 large unit panels by sequence, which consisted of 12,000 weather-resistant steel grilles of different sizes (see Figure 7).



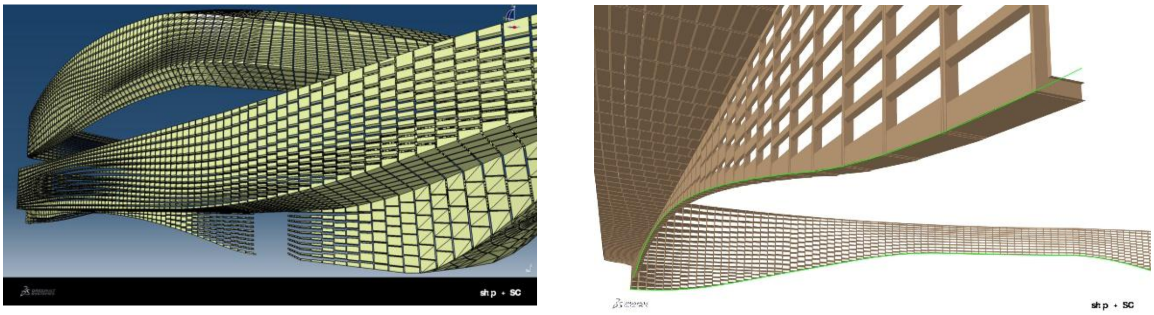


**Figure 7**: Barclays Center [5]

## V. Prospects

The emergence of BIM makes possible the accurate availability of design data throughout the whole project process from concept design, to blanking and fabrication, to field installation. However, lack of unified data exchange standards, the limited professional application capability of software, and many other factors still restrict the smooth transfer of full lifecycle information for the façade fabrication. Today, there is an increasingly obvious trend for integrated application of many technologies. Based on BIM, there will be more information technologies to be applied to the architectural envelope industry, promoting industrialization.

### Three-dimensional printing

3D printing is a rapid prototyping technology to form an object through layer-by-layer application of adhesive materials, such as powdered metal or plastic, on the basis of digital model files. 3D printing can help architects realize their ideas very quickly in the early stages and change ideas into real models, more visually and easier than elaborating on models in a virtual environment. It not only can make possible special shape and special form modeling output, but also has the advantages of low cost, fast speed, energy conservation, environmental protection, etc. A Chinese company is conducting the experiment of 3D printing a six-story building. As more and more new printing materials are available, the digital construction technology based on BIM and on 3D printing may possibly serve as an important information technique to promote the industrialization of the architectural envelope industry.

## Cloud

Concept design and detailed design can be done in the cloud so as to make possible façade design collaboration and data integration. In the cloud, we can transform a freely-drawn sketch into a geometric model by parametric design, and automatically generate a highly complex façade, so as to easily cope with various design changes and particular situations at a construction site. The cloud-based design process can, for each object, generate a detailed model that can be used for fabrication. The supplier's building component information collected on the cloud, such as information about doors and windows, can be used to generate accurate fabrication models. Through the expansion capability and collaboration functionality provided by the cloud, we can expand the application of concept design data to the fabrication stage, and, after modeling, directly break down the model into different assemblies reflecting the design intent, and then transform them into fabrication drawings and material lists, thus effectively connecting design and construction and helping to reduce the waste and rework usually occurring in traditional design and construction.

## BLM (Building Lifecycle Management)

As façade shapes become more and more complex, the information attached to façade fabrication increase accordingly, so it is increasingly significant to implement full lifecycle management of the architectural envelope with façade design information as the source. With full lifecycle information management, we can not only avoid project loss and project delay caused by improper or faulty façade design, but also quickly process all information related to façade fabrication and installation, so as to reasonably arrange construction periods and control production cost. The as-built data of the façade fabrication can also be used in the façade panel cleaning, repair, and maintenance stage.

BIM-based building lifecycle management (BLM) technology caters to such industry demand. BLM can help integrate the human resources, processes, and enterprise resource planning (ERP) application system that are related to architectural envelope products. Managers can then review the rationality, correctness, consistency, completeness, etc. of the BIM models and data provided by project-involved parties, and integrate complete information about the project, thus greatly reducing inefficient behaviors and the various risks for assets in the whole lifecycle (from conception to dismantlement).

In the architectural envelope industry, we need innovative management modes, new integrated processes, and new information technologies to improve collaboration efficiency and reduce waste typically arising in construction. There is an urgent need for now isolated design, fabrication, and installation processes to be integrated in a single environment, and BIM provides the best mode for doing so.

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**About CABR Technology Co., Ltd.**

CABR Technology Co., Ltd. is a share-holding high-tech company, a core enterprise of China Academy of Building Research. Through the decades, it has accumulated over 1,000 scientific research achievements; edited over 150 national and industry standards and codes which includes Curtain Wall codes; won 45 national awards and 184 provincial and ministerial awards; and secured 79 patents and software copyrights.