From File to Factory as an Ideal Process: a Case Study of Two Metal Pavilions in Bangkok

Apiwat Pattanasirimongkol[1], Walaiporn Nakapan[1*] and Saruta Kiatparkpoom[2]

[1]Faculty of Architecture, Rangsit University, Pathum Thani, Thailand
[2]Pin Metal Art, Bangkok, Thailand
[*]Corresponding author, E-mail: walaiporn@rsu.ac.th

Abstract

This paper documents the design and fabrication process of two metal pavilions in a new shopping mall in Bangkok. The pavilions were designed by a famous metal artist, with curvy distinctive features. Several parts of the process would have been a lot easier, such as direct transfer between the files and numerical controlled machines, the dismiss of unnecessary traditional drawings, as well as, the exact replicas of fabricated pavilions that should reduce cost and time. The research question is “What is the solution that can improve the design and fabrication process of the project that conforms with the From file to Factory process?”. The objective was to analyze and suggest improvements based on three characteristics of “From File to Factory process”, which are 1) Digital design, 2) Fabrication using numerical control machines, and 3) Seamless transfer between the files and the numerically controlled fabrication without a traditional drawing. The research method is qualitative analysis; the authors recount the process and did the cross-check. Afterward, an analysis was carried out according to the three characteristics of the File to Factory process where suggestions were proposed. The results also show the design and fabrication process of the two pavilions. In order to conform to the File to Factory process, it is recommended to use parametric design without going back and forth between software, as well as to output a digital that can be directly transferred to a numerically controlled machine.

Keywords: *Digital design, Digital fabrication, Parametric Design, Pavilion*

1. Introduction

1.1 Two metal pavilions in Bangkok

This paper documents the design and fabrication process of two metal pavilions in Bangkok. The pavilions were designed by a famous metal artist in Thailand in 2018. They were to be installed as indoor restaurants at a new shopping mall in Bangkok (The Icon Siam). The pavilions have got curvy and distinctive features that the draftsmen said it was impossible to do the drawings. So the metal artist consulted our team, after which, two pavilions have been modeled using Parametric Design (Rhino-Grasshopper). The ideal process for this project should have been following the “File to Factory” concept, which refers to the seamless merging of the design process into fabrication (Oosterhuis et al, 2004). From file to Factory describes a digital conceptualization and fabrication process - from digital design via parametric design, scripting and programming, ..., to the numerically controlled machine for digital fabrication. However, this project was not the case. The problems encountered include several changes in the models due to their relocation within the shopping complex; the pavilion models got changed several times after comments from the project interior designer; the metal finishing was done by another modeler using non-parametric software; the material take-off was done by an engineer who was not familiar with the digital design process; the engineer’s software handled a different file format; the factory has no experience in the fabrication of the curvy feature and the final product was not an exact replica of what has been parametrically modeled.

This paper describes what happened during the design and fabrication process as a case study of how the project has been done in professional reality (limited budget, relatively short time frame, and many stakeholders involved). Then we suggest what can be improved in order to achieve the ideal “File to Factory” process based on the digital design and fabrication process.

1.2 File to Factory process

File to Factory process allows a seamless fabrication of architecture in a complex digital workflow. The process can be executed by transferring the file to a numerically controlled machine without a single drawing being made (Staedelschule Architecture Class (SAC), 2019). This kind of architecture is made is called tectonism where the architecture is geometry aware of its shape and how it should be constructed (Schumacher, 2017). Examples of architecture that relied on this File to Factory Process is, for example, Thaluss White in the City by Zaha Hadid Architects (Zaha Hadid Architects, 2018), the MSc2 Hyperbody 1:1 prototypes by Faculty of Architecture, TU Delft (FORMAKERS, 2013), and the multi-story timber buildings for project Zembla in Kalmar, Sweden (Kaiser, Larsson and Girhammar, 2018).

According to Kas Oosterhuis (Oosterhuis et al, 2004), characteristic of the File to Factory process can be summarised as follows:

1. Digitally designed (Parametric design, scripting,...)
2. Fabricated using numerical control machines such as a robot, laser cutting machine,
3. A seamless transfer between the file and the numerically controlled fabrication without a single drawing being made.

2. Objective and research question

The objective of this paper is to investigate the design and fabrication process of the project. The objective is to propose a solution that conforms to the From File to Factory process.

We investigate how the metal pavilions have been designed and modeled and how they were fabricated. Then we investigate what prevented them from following the From File to Factory process. The research question is “what is the solution that can improve the design and fabrication process of the project that conforms with the from File to Factory process?”

3. Methods

The research method is qualitative analysis. The metal artist and the modelers (the authors of the paper) recount their personal experience of the project. Then the recounts were put together and cross-checked for correctness. The investigation includes the design and fabrication process, and the outcome according to Oosterhuis’s three characteristics from File to Factory process:

1. Digitally designed: we investigate how the design has been done as it was a project of a metal artist, which has been parametrically designed with the help of architects-parametric modelers.
2. Fabricated using numerical control machines: this part is discussed with the metal artist, who controlled the fabrication process with the help of an engineer-fabricator.
3. A seamless transfer between the file and the numerically controlled fabrication: the file format and transfer between architects and engineer-fabricator were investigated.

Next, the project process will be analyzed. Then suggestions will be given for improvement of the design and fabrication of the project.

4. Results

4.1 The design and fabrication process

The design and fabrication process of the two metal pavilions took the following steps (Figure 1):

1. The metal artist came up with an initial design of the pavilion. A quick sketch was provided, as well as an example of material (scrap metal panel). Physical models were made. The floor plan showing the location of the pavilion and interior surrounding were also provided.
2. The metal artist sought advice from the parametric modeler, after which, the pavilions were modeled using parametric design.
3. The pavilions were reduced from 3 (numbered as pavilion 612, 617/1, and 619/2) to 2 pavilions (615 and 606), and relocated to a smaller area, by the interior designer of the project.
4. The pavilions were remodeled using parametric design. The Rhino-Grasshopper team also checked the consistency of the model against the interior floor plan, ceiling height, dimension, interior walls, interior columns.
5. The metal artist readjusted the models and the designs were approved by the interior team of The Icon Siam. This step was repeated several times. At this point, the project took longer than expected.

6. The metal artist gave the Rhino model to another modeler because of a schedule conflict. The models were transformed into Sketchup models for metal cladding.

7. The models were given to structural engineers for structural analysis and material take-off, i.e. the length of the steel rods. The engineer used AutoCAD 3D.

8. The engineer was not able to measure the length of each steel rod in AutoCAD. Therefore, this task was reassigned to the parametric modeler.

9. The fabrication was done in a factory in Chonburi by an engineer-fabricator, under the supervision of the metal artist.

10. The pavilions were brought to the construction site in small parts (that fit the dimension of the service elevator) and were assembled on-site at the shopping mall by the engineer-fabricator, under the supervision of the metal artist.

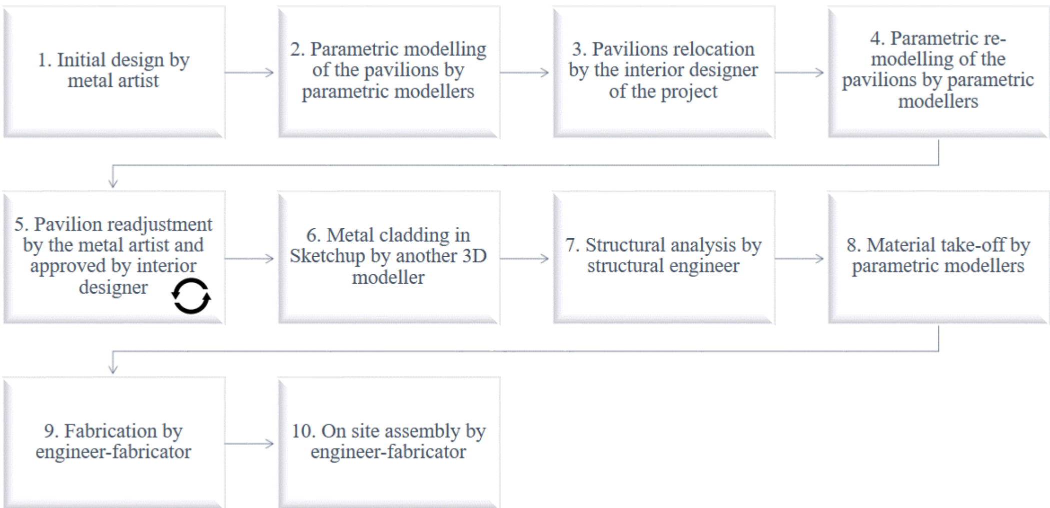

Figure 1 The design and fabrication process

4.2 Detailed description of the design and fabrication process

The metal artist came up with an initial design of the pavilion. A quick sketch was provided, as well as an example of material (scrap metal panel). Physical models were made (cf. figure 2 and 3)

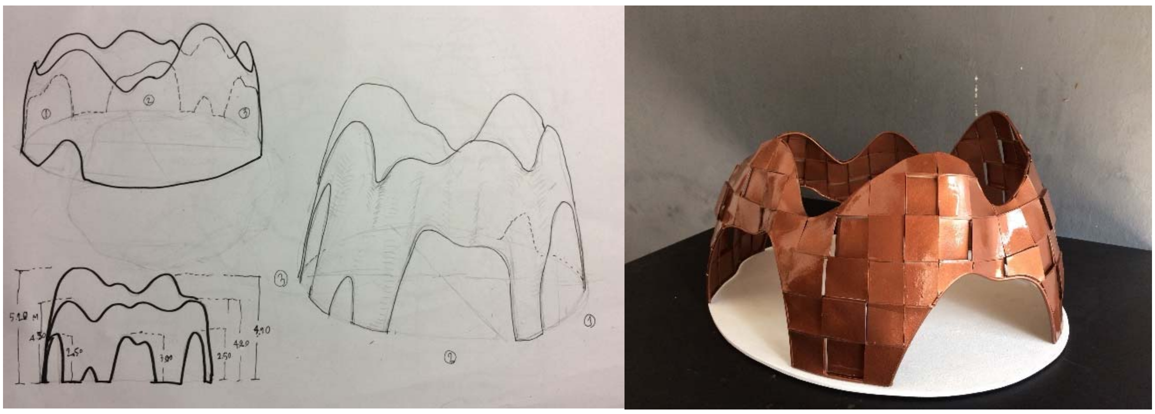

Figure 2 Initial sketch and model of Pavilion 617/1 (becomes model 615)

Figure 2 (continued) Initial sketch and model of Pavilion 617/1 (becomes model 615)

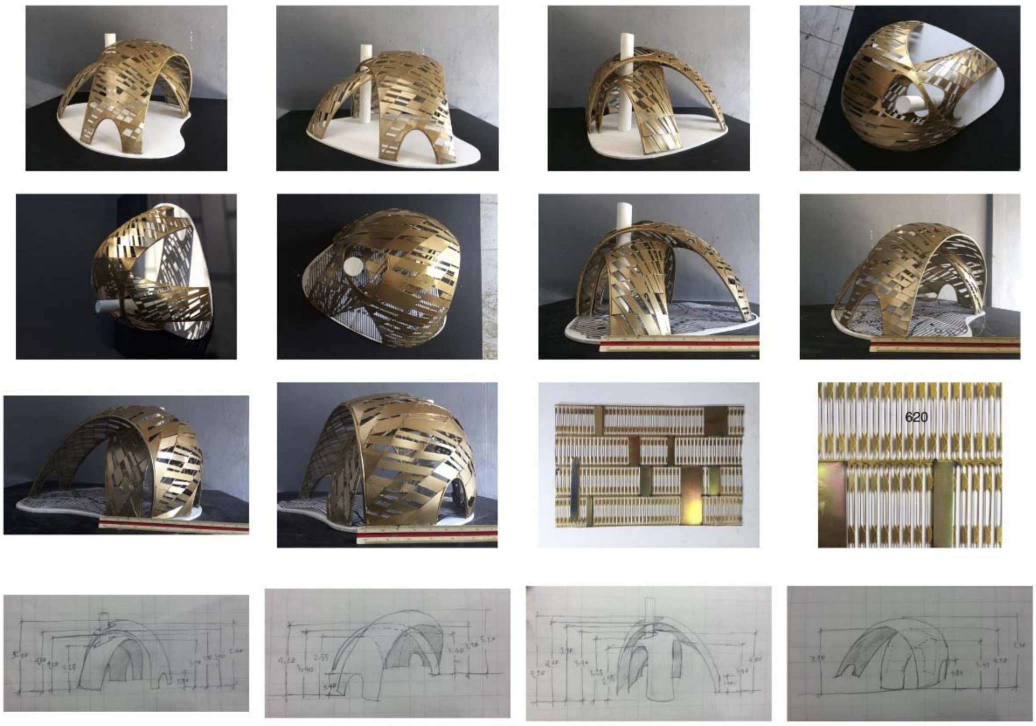

Figure 3 Initial sketch and model of Pavilion 619 (becomes pavilion 606)

The metal artist sought advice from the parametric modelers. Figure 4 shows initial parametric models of pavilion 615, and figure 5 shows initial parametric models of pavilion 619/2 (becomes pavilion 606).

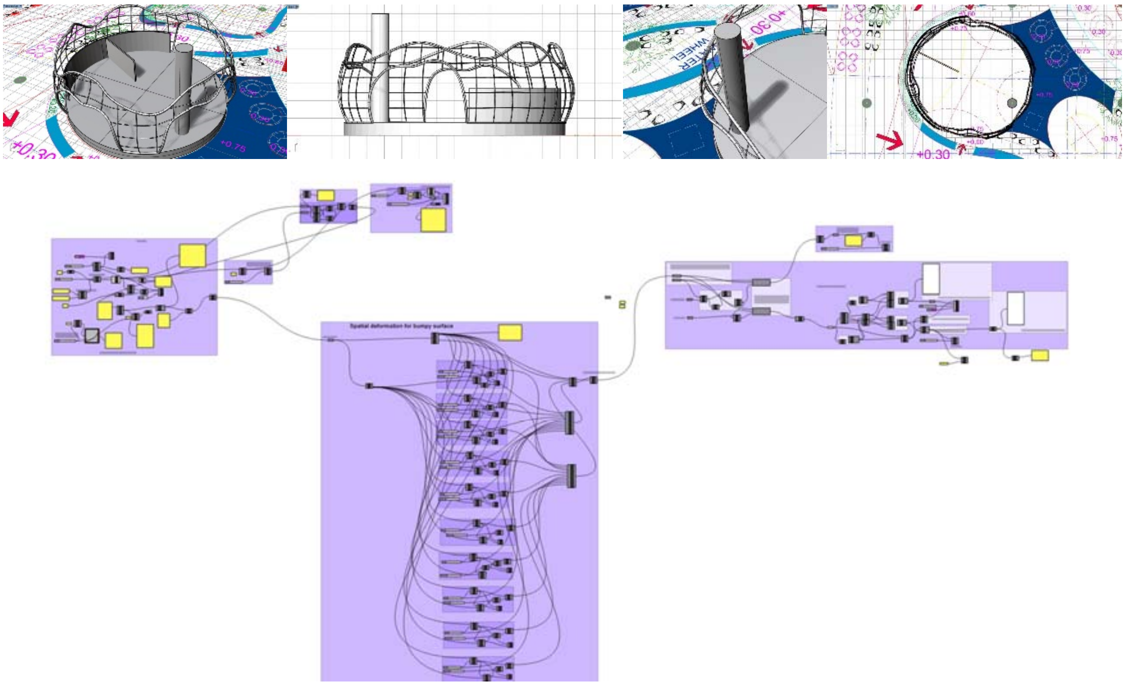

Figure 4 Parametric Modeling of Pavilion 615

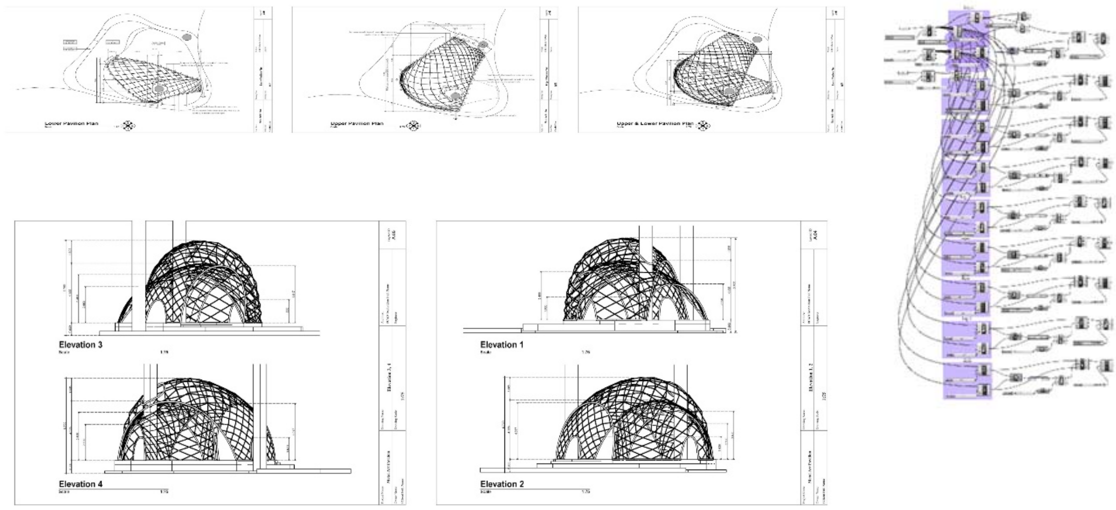

Figure 5 Initial design of the model 619/2 (becomes pavilion 606) after being parametrically modeled

As an example, we describe the changes occurred to the pavilion 619. The pavilion encountered the height limit of the ceiling height. After being adjusted several times to avoid the structure of the building, the artist decided to change the pavilion into a single piece of structure (cf. Figure 6).

Figure 6 Pavilion 619/2 was changed from two overlapping pieces to a single piece of structure

Then another change occurred due to the relocation of the pavilion, from 619/2 to 606. The interior designer of the project decided to adopt the initial design (two overlapping pieces) - figure 7.

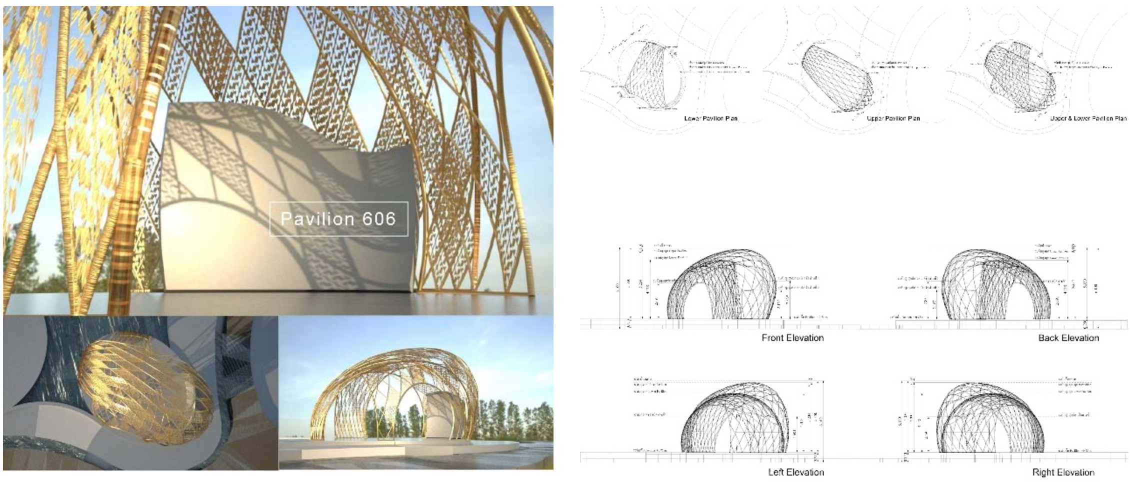

Figure 7 Final design of pavilion 606

For structural analysis, the parametric modeler has to export different file formats to the engineer who works with Solid Work. After trial and error, it was found that the .igs file was the one preferred by the engineer. Since the engineer was not familiar with structures with distinctive shapes, the parametric modeler also helped with the measurement of the length of the steel rods (cf. figure 8).

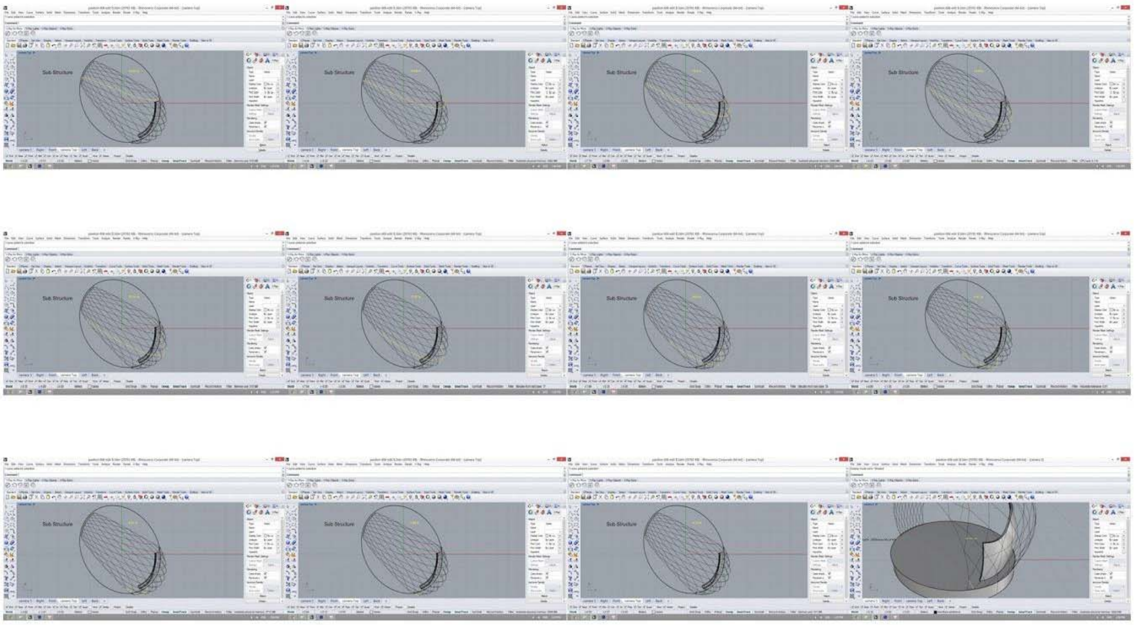

Figure 8 Material take-off process by the parametric modeler

The metal pavilions were fabricated in the factory in Chonburi, including the metal cladding. Figure 9 shows the pavilion 615 and figure 10 shows the pavilion 606 under construction. Next, the pavilions were brought to the construction site in smaller segments that fit the dimension of the service elevator. Then they were reassembled on site.

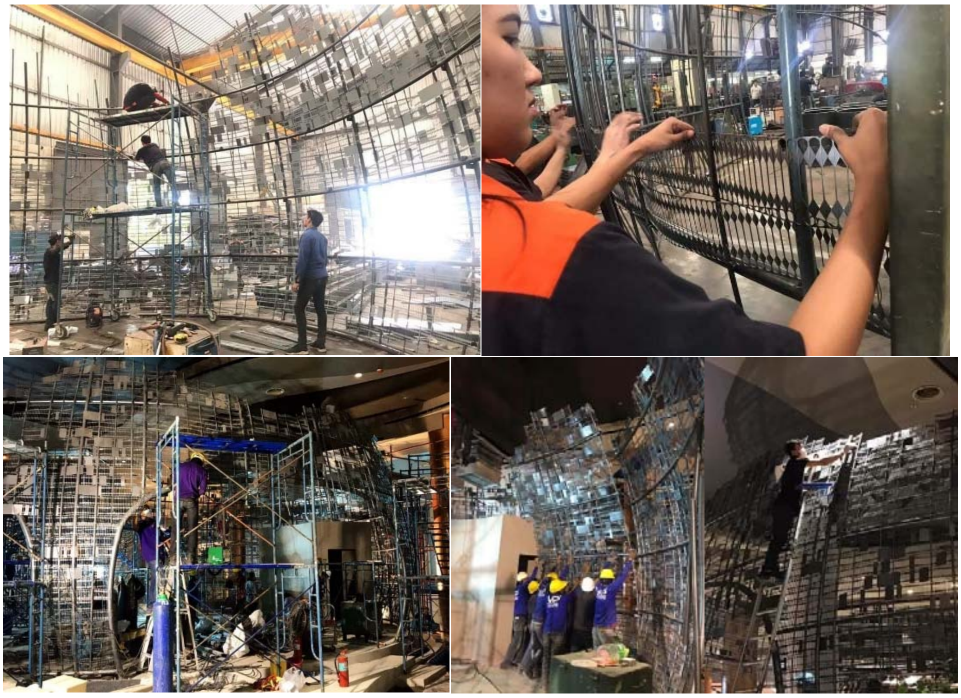

Figure 9 Pavilion 615 under construction

Figure 9 (continued) Pavilion 615 under construction

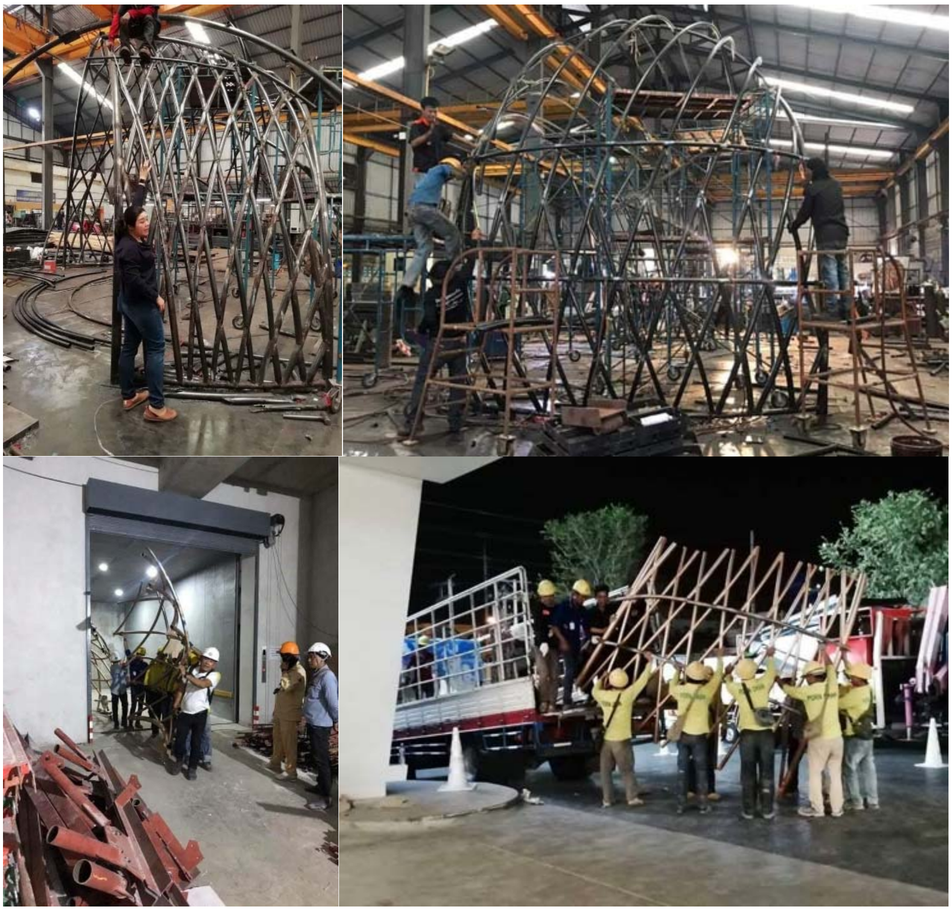

Figure 10 Pavilion 606 under construction

Figure 10 (continued) Pavilion 606 under construction

4.3 The finished pavilion

Pavilion 615 becomes a Korean restaurant (figure 11).

Figure 11 Result of Pavilion 615 “The Bibimbab Korean Restaurant”

Pavilion 606 becomes a Salad restaurant (figure 12)

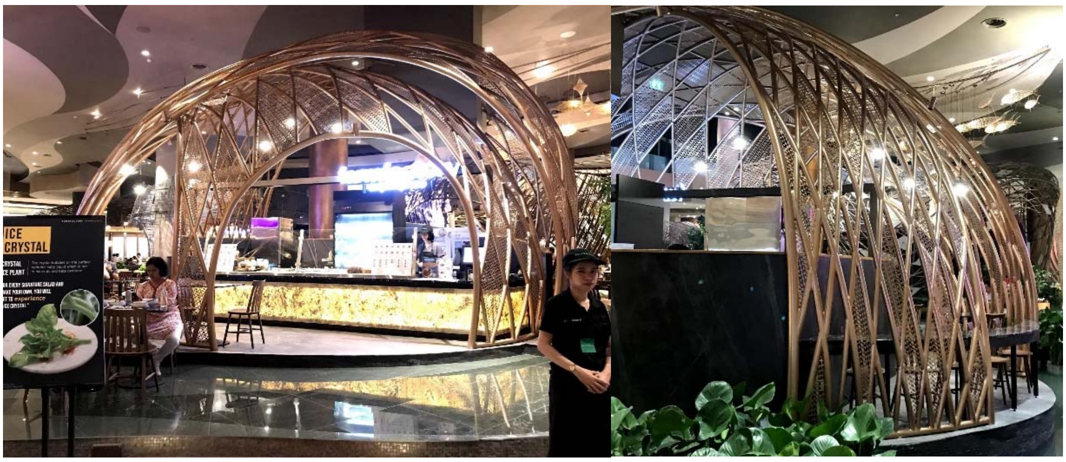

Figure 12 Result of Pavilion 606 “Farmfactory Experience” salad restaurant

5. Analysis and discussion

5.1 Analysis

The following analysis is structured based on the three characteristics of the File to Factory process design process (Oosterhuis, 2004).

1. Digitally designed

- The problems encountered include several changes in the models due to their relocation within the shopping complex. The pavilion models got changed several times after comments from the project interior designer. However, the parametric model allows minor changes in the model (adjustment of pavilion width, height, and shape) to happen quite easily.

- The metal finishing of model 615 was done by another modeler using non-parametric software (Sketchup) because of a schedule conflict. This process is reversible as the material take-off of the models cannot be performed using the parametric software further. (Sketchup was converted to STL format then sent to engineer). The metal finishing of model 606, however, was done in Grasshopper.

2. Fabricated using numerical control machines

- The factory could not fabricate the curvy feature because of their lack of experience and the final product was not an exact replica of what has been parametrically modeled.

3. A seamless transfer between the file and the numerically controlled fabrication without a single drawing being made.

- Traditional drawings were used for fabrication, and no numerical controlled machine was used.

- The length measurement of the metal rods was supposed to be done by the engineer. Unfortunately, he was not familiar with the digital design process. The engineer did trial and error with software (Solidwork, then AutoCAD), and file formats to open the exported file from Rhinoceros in a stable way. He also struggled with the material count and sizing through trial and error. After several discussions with the parametric modeler, the task was reassigned to the parametric modeler.

5.2 Suggestions

1. Digitally designed

- Parametric design is an essential upstream part of the digital design process, so it is highly recommended. Without it, all the rest of the File to Factory process cannot occur. However, the digital design tool (such as scripting) should also work, as long as it gives digital output that can be passed on to a numerically controlled machine.

- Parametric design has proved to be able to handle several minor changes in the models efficiently. However, there should not be a set zero, which will make it difficult for parametric design to handle.

2. Fabricated using numerical control machines

- For manual fabrication, the process can be enhanced using Augmented Reality (AR), such as Fologram's holographic construction technology (Jahn et al, 2019). The model can be navigated in a physical environment through MR devices (HoloLens + Fologram). This will allow a precise bending of the metal pieces or an exact placement of the steel rods.

- In the case of mass production, it is recommended to use a robot for material cutting and welding. The initial cost of investment is high but is returnable in the long run.

3. A seamless transfer between the file and the numerically controlled fabrication without a single drawing being made.

- There should not be going back and forth between software (such as Rhino to Sketchup), which broke the parametric process and the model becomes irreversible. The structural design should be done in Grasshopper (such as Karamba plugin for structural analysis). Material take-off should be done by the parametric modeler.

5.3 Discussion

Following aspects of the projects were also observed:

1. Economy of the project

- Most of the budget goes to the engineer/fabricator, the modeler did not have sufficient budget to carry on several changes of the model. It is suggested that an important part of the budget should be dedicated to modeling and material take-off.

2. Timeframe of the project

- Apart from a limited timeframe of the project schedule, it is important to note that several changes in the model make it even longer than expected. This results in a schedule conflict between stakeholders.

3. Collaborative process of the project

- Modelers were not allowed to directly contact the interior designer of the shopping mall. This makes it difficult to finalize the models. For model 606, the designer would like to express her creativity but was not approved by the interior designer of the project. The result was the restart of the design.

- The engineer specified the cross-section dimension of the metal rods. This dimension was reduced by the designer for a lighter expression of the structure. There is no problem with remodeling but it has a problem with the interior designer, who found that it was not the same as the initial proposal.

6. Conclusion

The project is a case study of the design and fabrication process. It was documented to analyze based on the File to Factory process, using the three characteristics of the process. Suggestions were made so that the project follows the File to Factory process as an ideal process. Several parts of the process would have been a lot easier, such as direct transfer between the files and numerical controlled machines, the dismiss of unnecessary traditional drawings, as well as, the exact replicas of fabricated pavilions that should reduce cost and time. Several aspects of the project reality should be considered, such as economy, timeframe, and collaborative process. These are the actual causes that prevented the project to conform with the File to Factory process. It is likely that the File to Factory process would become a reality if it was set up from the beginning by all stakeholders, especially the artist, the fabricator, and the shopping mall. This could have been a demonstrative project to showcase the potential of digital design and fabrication.

7. Acknowledgments

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