

## DIGITAL CATALOGUE

*A computational implementation of Korean joinery system in the design of a transformable disaster shelter*

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**Abstract.** With the help of Building Information Modelling (BIM), the digital catalogue of all the 44 components of Korean joinery system is developed for the application of their tectonic principles in the design of a transformable disaster shelter. Based upon the components of three primary bracket styles (Jusim-Po, Ik-Gong, and Da-Po) of traditional Korean joinery system in the catalogue, the parametric modifications of the components and their rearrangements are performed for various iteration of the disaster shelter. The usage of Korean joinery system in assembling and disassembling the components enhances the transformability and the reusability of the shelter. This paper demonstrates the computational implementation of Korean joinery system and the design process of a transformable disaster shelter.

**Keywords.** Digital catalogue; BIM; Korean joinery system.

### 1. Introduction

With the increasing concern of natural disasters, continuous studies on emergency relief shelters have been actively promoted and provided the development of prefabrication method and assembly system of the shelter. However, one of the disadvantages of current disaster shelter designs lies in its after usage. Numbers of projects revealed the inconvenience of the structure after the usage such as required storage areas, auctioning of the product, recycling process and littering of the materials. The significance of this research is in maximizing the reusability of the building components through their parametric changes and rearrangements with applying traditional Korean joinery

system.

Traditional Korean architecture is referred to as “moving architecture” that allows the reuse of building components with its flexible joinery system in assembly and disassembly process and prefabrication method. All the 44 components of Korean joinery system become a series of modules in a digital catalogue. The components of the digital catalogue were built within Building Information Modelling (BIM) environment. The digital catalogue allows a user to explore various morphological transformations in building components and its design iteration through the parametric changes and rearrangements of joinery components saved in the catalogue. The parametric conditions in BIM allow flexible changes in form, dimension and assembly of the components. The unique setting of working with the components, BIM software allows its users to easily modify the general characteristics of components through their parametric changes (Lee, Sacks and Eastman, 2006). The aim of the study was focused on the possibilities of parametric design using BIM system for industrialization of modernized Korean traditional buildings (Kim et al, 2010). The studies of construction methodology of traditional Korean architecture from the bottom-up process using BIM software was achieved during the research.

In this paper, the implementation of the digital catalogue is introduced in the process of making various transformation outcomes of a prototype disaster shelter.

## **2. Disaster shelter**

The typology of disaster shelters can be divided into general system and movable system (Moon and Lee, 2006). The general system is such as paper-tube structure and ferroconcrete structure for long term usage according to climate and nature feature. The movable system defined as the use of mobility and flexibility, light weight and economical efficiency. The only concern is the matter of supply and efficiency. Disaster shelters are no longer useful after the disaster end (Lee, Kim and Lee, 2004). In some cases, disaster shelters are being disposed and the disposed components become another hazardous atmosphere onto the site. FEMA disaster trailer was effectively distributed during hurricane Katrina. The immovability and prefabricated structure was able to mass-produced and delivered onto the site in a short period of time. However, its prefabricated materials caused health problem by polluting the interior air through the hazardous levels of formaldehyde used in its premade materials. Also mass production of the product flooded the market after its use, where trailer business dumped their products. The development of reusable components is very significant that such flexibility and mobility in the modification of the shelter can be achieved through components reassembly.

### 3. Traditional Korean Joinery System

The advanced tectonic principles of individual components embedded in traditional Korean joinery system effectively led to an easy assembly and disassembly, fast construction, easy relocation of a structure and the reuse of components (Chong, 1974). Traditional Korean architecture is not a one massive structure but multiples of individual components assembled together. The wide varieties of joineries effectively led to easy assembly of the components. The case of repairing works in traditional Korean architecture depicted its quality of reusability of the components and relocation of a building structure. Traditional Korean wooden structures used bracket system as a main structural element in a building. Bracket system where different members are assembled through various joineries needs not only its strength in each member but also strength in those of joining connections. (Kim, 1993). In this paper, categorization of joinery resulted in focusing on a specific unit in traditional Korean architecture-the bracket systems.

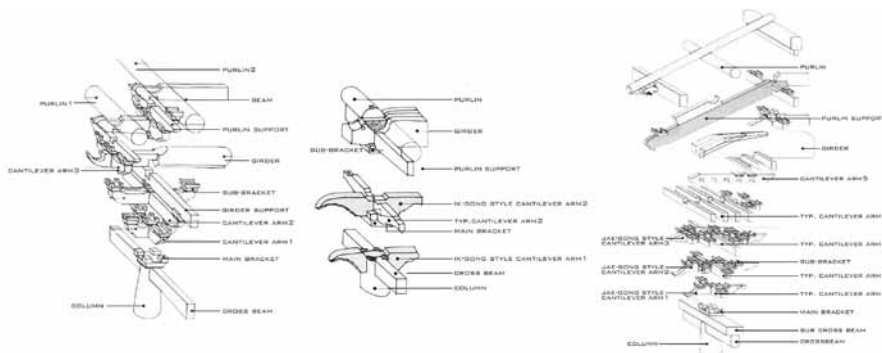


Figure 1. (a) Ju-Sim-Po, (b) Ik-Gong, (c) Da-Po

The three main types of bracket systems found in traditional Korean architecture are Ju-Sim-Po style, Ik-Gong style and Da-Po style of bracket system. Ju-Sim-Po style as the first bracket system introduced in Korea was favourable with its simple construction with relatively strong support. Ik-Gong style articulated the beauty of form through creating a simpler version of Ju-Sim-Po. Da-Po style was the most complex system with added number of components which enable to support heavier roof structure. Especially in the case of traditional wooden structures of Korean architecture, flexible joinery and connections in building components benefit effective relocation of its building to other site through dismantling the components.

#### 4. Digital catalogue

Jean-Nicolas Louis Durand (1760-1834) investigated on the system of design using simple modular elements in the *Recueil et Parallèle des Édifices de Tout Genre*. Comparative taxonomy, a table of architectural species introduced in the *Recueil* created a basic foundation of the digital catalogue where the idiosyncratic objects emerged from manipulation of architectonic elements during the form-making process. The comparative taxonomy in architectonic elements through the parametric modifications on existing components can generate various iteration of form making process of the disaster shelter. The wide varieties of traditional Korean joineries were selected as the main component family to be modified.

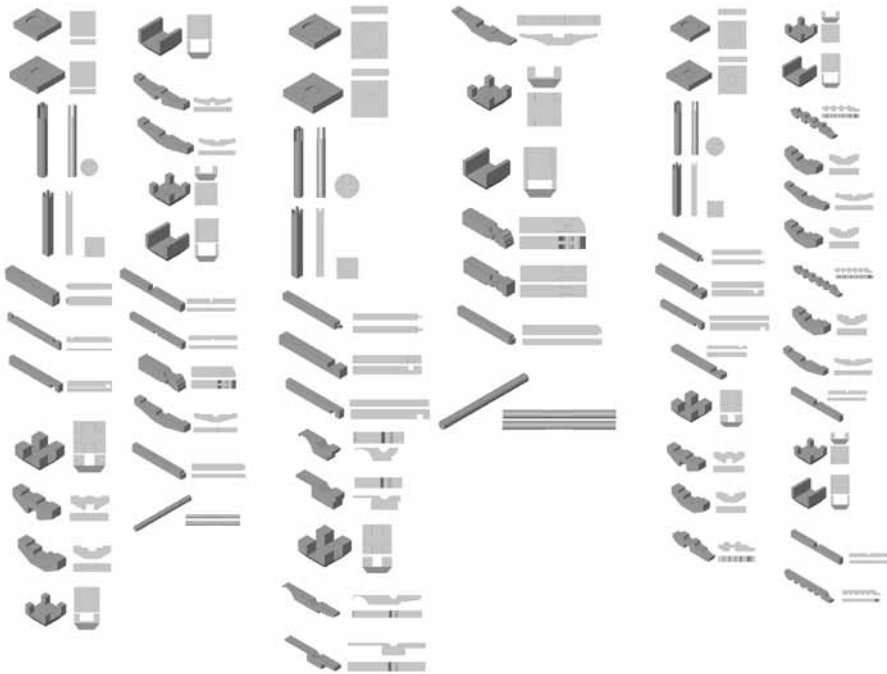


Figure 2. Existing component group J, I and D (constructed in Revit Architecture)

Total number of the 44 existing components was created from *Ju-Sim-Po*, *Ik-Gong* and *Da-Po*. All the components become a series of modules in the catalogue for their parametric changes and rearrangements within Autodesk Revit environment. Any single module or the combinations of the multiple modules from the catalogue can be employed for easy fabrication, removing, reattaching and acting as a reusable structural element.

4.1. METHOD OF CATEGORIZATION

Joineries were categorized under four groups based on the function and its use in existing traditional structure. The four groups are floor, column, brackets and roof. Categorization of components enhances the usability of the components in building construction. By categorizing each component to its function, a user can have clear understanding in selection of each component. The existing components will be divided into three main types of bracket systems: group J for *Ju-Sim-Po*, group I for *Ik-Gong* and group D for *Da-Po* styles.

Table 1. Labelling of existing component groups

Component group Ju-Sim-Po	Component group Ik-Gong	Component group Da-Po
J_01 ~ J_15	I_01 ~ I_11	D_01 ~ D_17

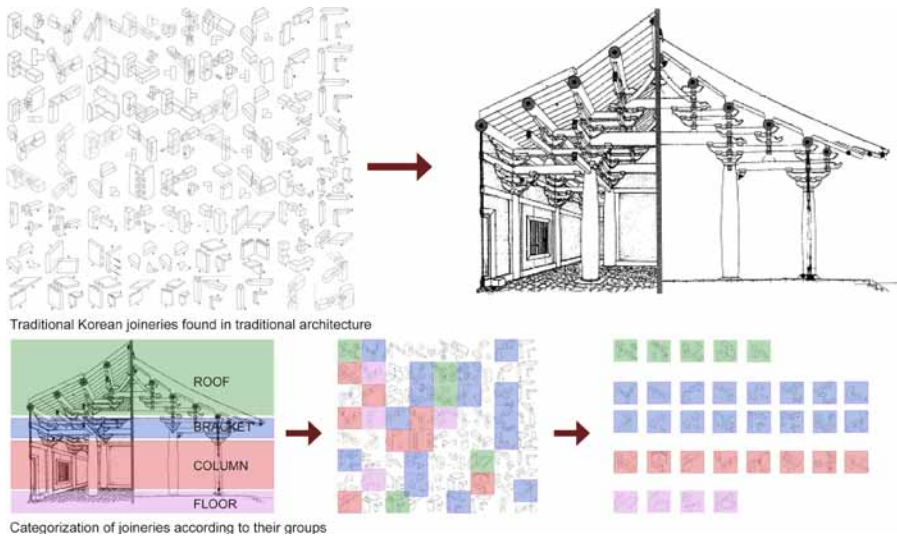


Figure 3. Categorization of joineries according to function in traditional architecture

4.2. DEVELOPMENT OF BASIC MODULES

The existing components shown in Figure 1 were created in Revit environment as 44 basic modules for the construction of a shelter under the parametric settings of constraints. Groupings of existing 44 components were based on their function in traditional Korean wooden structure: floor, column, bracket and roof.

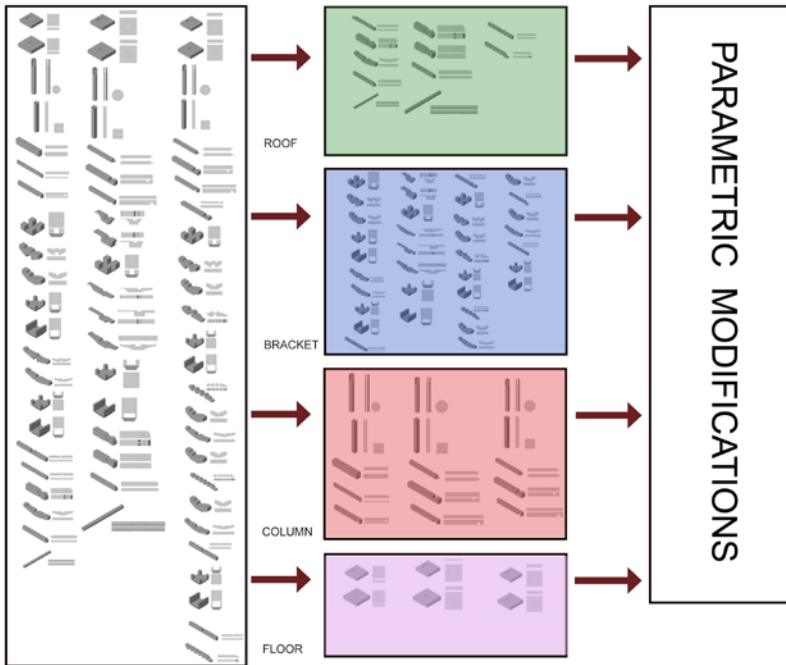


Figure 4. Categorization of existing components

#### 4.3. COMPONENTS MODIFICATION

The idea of generating new components is to cross reference these restrictions in existing components. By adding the values of different joinery types between mortise-and-tenon joinery and simple lap-joinery, usages, locations of joinery and piercing of the component, existing components require its changes in form and dimension through parametric modifications (Namgoong et al, 2008). In the proposed catalogue, an individual component in the joinery system is defined with four design factors such as 1) joinery type, 2) use of joinery, 3) location of joinery, and 4) piercing of the member. With modifying the contents of each design factor, the user of the digital catalogue is able to generate a new component. According to user's preference, the component parameter can be substituted to change the form and its relationship to the assembly units. For example, when the changes of the design factors in the given component are made as in table 2, a new component is generated as shown in figure 5.

Table 2. Labelling of existing component groups

Type of joinery	simple scarf joint	mortise and tenon joint
Use of joinery	rectangular lumber + board	rectangular lumber + rectangular lumber
Location of joinery	end of lumber + end of lumber	inside of lumber + inside of lumber
Pierce	none	present

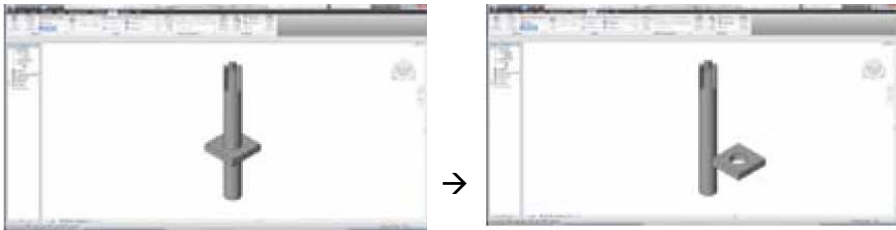


Figure 5. Demonstration in change of joinery type, use, location and pierce

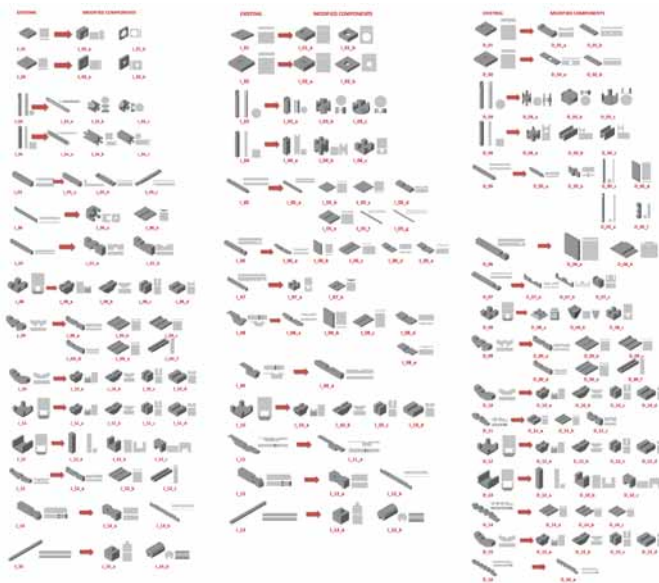


Figure 6. Total number of components in digital catalogue

Each of total 44 components in group J (*Ju-Sim-Po*), I (*Ik-Gong*) and D (*Da-Po*) were modified accordance with the changes in four design factors of each component. From original 44 components, total numbers of 180 components were generated in digital catalog as shown in figure 6. Modified components will be grouped correspond to their mother component. For example, modified components generated from the existing component in floor group

will remain in same group category. Each existing components with its modified components will be grouped under four main categories: floor, column, bracket and roof. However, the modified components changed its function and dimension through the parametric modifications of the four categories. Therefore the components need to be regrouped according to their new function and performance. Figure 7 indicates the reshuffling of the components that have distinct forms and dimensions unlike the rest of the components under the same grouping. The evolving of the component and its new generative constructions now cross reference the components function and its dimension.

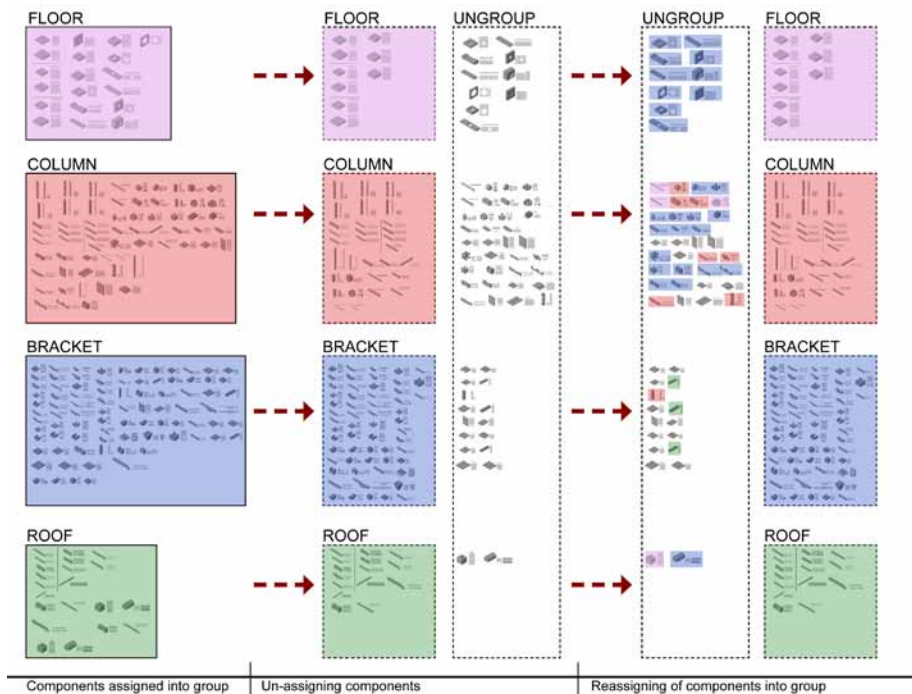


Figure 7. Reshuffling of components according to the function and dimension

Grouping of the components accordance to the function can guide the users to easily pick and choose the component to be applied during the design process. Wall/floor panels group was added to the original four groups such as floor, column, bracket, and roof, in the process of generating total 180 components with changing the design factors of the original 44 components.



## 5. Transformations

Design of prototype shelter was made through assembly of components in five groups (floor, column, bracket, roof, and wall/floor panels) under the digital catalogue. By analyzing individual components with its connection and method of construction, specific types of components were chosen for experimentation. A prototype of disaster shelter is designed with 17 component types and 80 individual components as shown in figure 8.

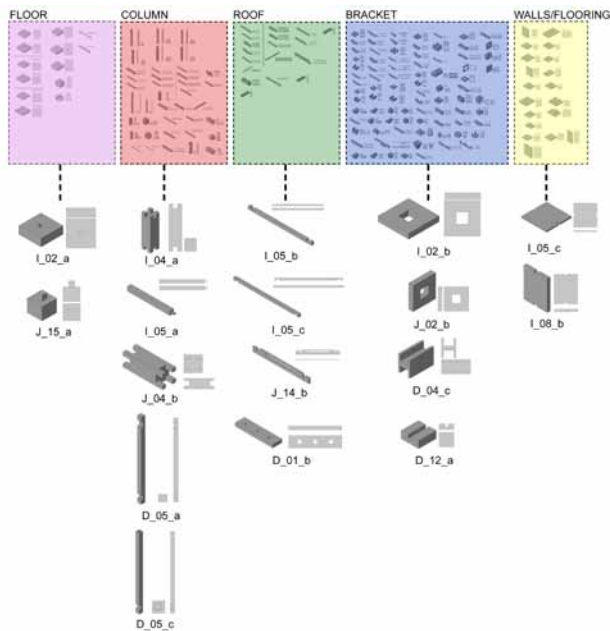


Figure 8. Components used in in the design of a prototype disaster shelter A

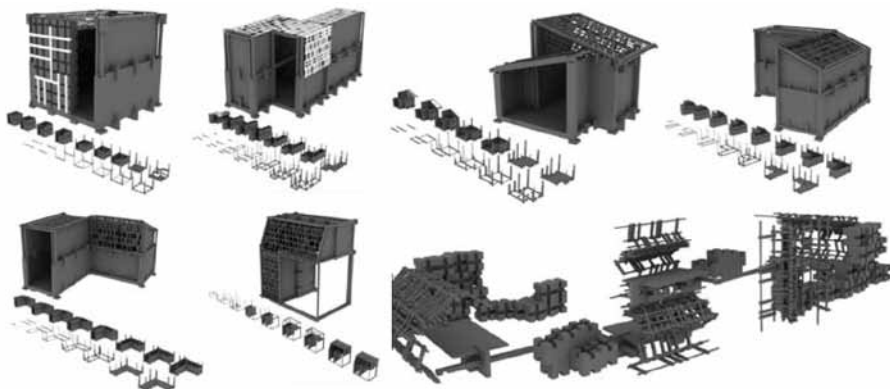


Figure 9. Morphological transformation of a prototype A (top-left) into others

The assembled prototype A can be dismantled and recreate as a sub-units or furniture layouts. It transforms into a different prototype as shown in figure 9. Not only the shelter design changes its form into sub-structures but also it can change its form as a shelter design such as through adding and subtracting extra components.

## 6. Discussion

In this paper, digital catalogue was utilized in the design process of a prototype disaster shelter. With the use of 17 components from 5 categorized groups, prototype design can be transform through the reconfiguration of the components. In fig. 9, structure not only transforms into another form of structure but also various furniture layouts can be produced. Design of furniture or individual resting units can be effectively used for the public after use of the shelter. Morphological transformation of a disaster shelter through the application of traditional Korean joinery system was performed to suggest a flexibility and mobility in a prototype disaster shelter design. It shows the possible application of BIM parametric environment in prefabrication and individual component generation. The significance of digital catalogue is in that each component can be user dependant. The catalogue allows a user to assign various parameters to the variables of each component according to its usage. By assigning different parameter, the component has flexibility for generating various joint connections enhancing the morphological transformation of a prototype shelter design.

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