Study on the Concept of "Architecture" to Describe Construction Products

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Abstract:

The concept of "Architecture" is one of the methods to compose artificial systems such as products, organizations, or construction processes. This concept focuses on the interfaces between the elements of an artificial system, because interfaces tend to identify the characteristics of the whole system. Two axis of "Architecture" - "Modular–Integral" and "Open–Close" - can be helpful in classifying construction products. The characteristics of "Architecture" get more 'Open,' when 'Open' information usage increases in terms of "Architecture." "Modular Architecture" is one of the key factors of "Open Architecture," because "Modular Architecture" reduces confusion of information by simplifying interfaces. This paper discusses a method of identifying construction products with the "Modular-Integral" axis.

Keywords: Architecture concept, Open Architecture, interface, modular aspects

1. Introduction

Construction is a complicated artificial object, and it is difficult to grasp whole of the construction system perfectly. In these days, many kinds of technique related to construction have made remarkable advances, so a lot of elements of construction system have been getting complicated steadily.

Various factors work on an artificial system, and the composition rule and grammar of the system have some tendency. Accurate knowledge of composition rule and grammar is quite important to create a certain special system, and it is necessary to analyze what the factors (Nodes) are to compose total system and how they are composed. But it is difficult to make clear what Nodes are directly, so careful observation of the Nodes is quite important to understand whole of a system.



Figure 1: Composition of Artificial Product

There are several methods to analyze artificial objects, and "Architecture" concept is one of them. Basic viewpoint of this concept is to focus on the interfaces between components of artificial system such as product, organization, or process.

Generally, "Architecture" is defined as follows: "how we split the artificial system into modules, how to allocate functions to each module, and how to design and coordinate interfaces among different parts, or modules."

Originally, this concept came from Architecture (Building). There are many complicated parts in building components, and original concept of "Architecture" is the situation of a mass with many complicated elements. Thus, computer processors were designed with this concept at first, and after that, many computer components were studied with this logic. Finally, several industrial fields, such as automobile, motorcycle, and computer software, were analyzed with "Architecture."



Figure2: Transition of "Architecture" Concept

2. "Architecture" concept for "Open"

2.1 "Architecture" for artificial objects

Construction is a complicated object, and it is almost impossible to understand whole of the system in these days. The concept of "Architecture" is one of the ways to analyze artificial objects.

In this paper, the definition of the concept of "Architecture" for construction systems is 'the fundamental rule about composition (method of structure) and the fundamental technique about structure (method of construction) of an artificial system, from the point of view of how to divide the system into some elements (modules) and how to design their joints (interfaces).'

2.2 Classification of "Architecture"

In this paper, construction system is analyzed with the concept of "Architecture." There are two typical indexes in the concept of "Architecture"; "Modular–Integral" and "Open–Close." An index of "Modular–Integral" is based on the situation of interfaces between elements. If a system is "Integral Architecture," the design of parts composing the system must be adjusted to each other and optimum coordination must be sought for that particular system to fully elicit its potential performance. In contrast, "Modular Architecture" provides standardized interfaces linking different parts and modules. Thus, one can produce various products by putting together independent parts as long as they are compatible with these interfaces.

"Open Architecture" is a kind of "Modular Architecture" with an industry-wide standardized interfaces, under which parts and modules can be gathered across corporate borders. "Open" is based on the concept concerning the common use coverage of the information of interfaces, and it is possible to make interface's information simple in "Modular Architecture." This is the point of the relation of "Modular" and "Open."

| | | MODULAR | |
|---------------------------------------------------------------------|------------|-----------------------------|--|
| CLOSE standard interfaces OPEN customized interfaces | motorcycle | multipurpose computer | |
| | camera | file with temporally camera | |
| | | bicycle PC | |

NITEODAL

Figure 3: Typology of "Architecture"

2.3 "Open Architecture" as the concept of social consensus

The concept of "Open" is used in a lot of fields in these days, and the mean of this concept is not unified. In this paper, "Open"/"Close" is defined as follow; 'the concept concerning the common use coverage of the information of interfaces for creation, innovation and maintenance of a system'. "Open" means that this coverage is increased, and "Close" means this one is decreased. Thus, the concept of "Open" is not a system characteristic but the concept for social consensus.

There are two important view points, Target and Level, to understand the "Architecture" of systems. At first, Target of "Open" is considered. It is possible to classify with the purpose of "Open." "Architecture" of each "Open" system is completely different because of the purpose. There are three classes mainly; for competitors, for sub contractors and for customers.

The interfaces of 'locks' for doors are "Open" in their industries, so this is a typical example of "Open" for competitors. The size of 'raised floor system' is unified, and then floor finishing companies (sub contractors) get influence from this size and shape of floor system. The interfaces of 'kitchen system' for cooking equipments such as a dish-washer or an oven are standardized for customers.

Secondly, the "Open" Level is explained as the other important point. The glass for typical doors is "Open" for every sash company, but the situation of fire limit glass is completely deferent from typical one. It is necessary to make information about fireproof specification to create a fire limit glazed door including frame of that door. So only manufacturer who has special knowledge about fire limit glass can create the product like that in this case. But it is possible to install both of typical glazed doors and fire limit doors into any construction system and these two "Architectures" are deferent types.

There are five methods to develop "Open" of a system. First one is to open the information aggressively. Second is to make that information to be accessed by anyone in that field. Third is to make the information attractively, and to make a situation everybody in the field would have an interesting in that information. Fourth, if many people in the field become familiar with that information, "Open" would accelerate. Final one is to decrease quantity of the information for creation, innovation and maintenance of a system, so "Modular" is one of the ways to develop "Open."

| Table1: | The fact | ors to pron | note "Open' | of a | system |
|---------|----------|-------------|-------------|------|--------|
|---------|----------|-------------|-------------|------|--------|

| chitecture" |
|-------------|
| |

In this paper, "Modular Architecture" is analyzed mainly, because it is possible to create and innovate a system with the only knowledge about the demonstrated interfaces. This is a quite important factor for "Open" as a social consensus. Thus, it is not necessary to have any information or knowledge about the part or element that is not concerned with the target in that case. On the other hand, if a system is not "Modular Architecture," every stakeholder need spend a lot of energy to exchange information. So "Modular" is a very important factor for "Open" at this point also.

"Modular-Integral" axis is based on the characteristic of each domain, organization or project, and it is difficult to replace the type of certain system. With "Modular Architecture," the independence situation of each module is maintained, and evolution of a system is accelerated. On the other hand, standardization of interfaces between modules causes a restriction of the range of total system performance. But "Architecture" shows the only the type of tendency of a system, and this concept does not discuss which is better or so.



Characteristics of "Modular"

| 1 Cause of Complexity | 2 Reduction Method of Complexity | |
|-------------------------------------------------|--------------------------------------------------------------------------------------------------------|--|
| Increase of Number of Elements | A Hierarchy Structure B Integration of Interfaces ?H.Simon " <i>The Science of Artificial</i> ") | |
| Irregularity of Interaction between Elements | C Establish Rules | |

Figure 4: Diagram of Characteristics of "Modular"



Figure 5: Chart of Performance ("Integral Architecture" and "Modular Architecture"). Modular Architecture" makes limited performance quickly (ex; Dell PC), but if it is necessary to have high specification, the system must be "Integral Architecture."

3. "Architecture" concept for construction system

3.1 Analysis of construction product

There are two important points to classify the types of "Modula-Integral"; the interface rule between elements and the relationship between functions and components. It is necessary to understand the tendency of system structure with these points.



Figure 6: Factors for Typology of "Architecture"



Figure 7: Diagram Factors for Typology of "Architecture"

3.1. The Rule of Interfaces

Firstly, interface rules are analysed with description. Modular Architecture has standard interfaces and can replace elements easily. Modular construction type does not need special arranges to adjust on the site. Integral Architecture has more complicated and independent interfaces, so it is difficult to change each part normally. But the total

performance of Integral type is sophisticated in many systems. It is necessary to arrange in order to adjust each other on site in integral construction Architecture.

Architectures of Japanese construction and of UK construction are described with Hierarchy expression. There are many interfaces around the rise of external wall, so it is possible to understand the difference between these Architectures.

The standard detail of Japanese construction is typical integral Architecture, and UK's standard is modular Architecture at the standing point of interface rule. This situation is not only around rise of external wall but also in many other parts.



Figure 8: Rule of Interface(1) In construction projects, it is possible to understand the "Architecture" with the fitting of elements on site. Some elements are installed without any arrangement, But some other elements need to be arranged to fit other elements.



Figure 9: Rule of Interface (2) Japanese standard detail is "Integral Architecture." This part of UK detail is "Modular Architecture" completely.

3.1.2 The Relationship between Functions and Elements

Secondly, the relationship between sub functions and structural elements is analysed. This relationship of modular type is so simple, and one function corresponds to one structural element. For example, concerning PC, the function of operation depends on CPU, and modem has just one function, communication.

Opening is analysed to understand the relation of these items in construction works.

Japanese standard detail of reinforced concrete buildings for opening is integral Architecture; plural structural parts tend to create just one function. UK standard is completely different; one structural part has one function, and one function corresponds one part.

? relationship between main and sub function



Figure10: Relationship between Function and Element (1) For example, cell phone is "Integral Architecture." Key, screen and frame are used for telephone, e-mail and game. On the other hand, customized PC is good example of "Modular Architecture," CPU-operation, HD-data save, modem-communication...



Figure 11: Relationship between Function and Element (2) The standard detail in Japan is integrated with function and elements. The sub functions of UK detail are divided into many numbers, and each function is suited by one or two elements. This is a typical "Modular Architecture."

3.2 **Analysis of organization Architecture**

It is difficult to analyse the Architecture of construction organization directly, because it is possible to understand only organization chart at the standing point of contract. In many projects, the role and the responsibility of each subcontractor are determined to adjust to each project, and are slightly different from contract condition.

It is possible to make clear real organization Architecture with common sense of project managers and site managers. In this paper, the opinions about subcontractors of Japanese site managers, who have experiences to have projects in Japan and in UK, are studied. At first, important roles and actions in construction works are listed, and the roles and actions that are the perfect duty items are excluded. Then five items are selected to get data from site managers.

Then, site managers answered about each of the items whether they expect that subcontractors should make an action and take a responsibility or not. The point is site manager's expectation for sub contractors. The questions focus on the relationship between subcontractors, so every question is about the expectation of one subcontractor's action or responsibility to another subcontractor. Three Japanese site managers who have experiences to work on Japanese construction projects and UK's ones answered those 5 questions about interrelation between each subcontractor.

They answered with YES or NO, where Yes means integral organized system and No means modular organized system. The numbers of YES is counted on a matrix, and total numbers of YES is completely deferent; Japanese organization system is integral Architecture, and UK system is modular Architecture.



Process "Architecture" Study Integral Index of Standerd Opning

Figure 12: Integral Index of Organization. In Japanese construction projects, sub contractors have quite strong relationship each other. They have a feeling to have a responsibility for whole of the project also.

3.3 The relationship between aspects

Architecture designates not only situation of each aspect (product, process, organization and so on.) but also total structure of whole of the system with interrelation between each aspect. Artificial system has many aspects, and it is impossible to understand that system without any analysis of the relationship between aspects.

With the descriptions, it is possible to understand that Japanese construction system has great tendency as "Integral Architecture." There are several researches about "Architecture" in deferent industrial fields such as automobile industry and computer industry, and almost every paper points out about Japanese system as "Integral Architecture" in every aspect. Although construction is a complicated artificial object, Japanese construction has a tendency to be "Integral Architecture" in all of the aspects.

If every aspect is "Integral Architecture," it is difficult to create a modular product with that system, because every member in that system tends to establish the idea for "Integral" system.

4. Discussion: "Modular Architecture" for "Open" of a system

The recognition of the tendency of existing construction system is analysed, and it is possible to recognize some tendency. "Modular Architecture" has a merit for the decomposition of product system, because the rule of interfaces between the elements is simple, and the relationship between function and structural components is simple also. The flexibility to divide product parts is based on the design concept of "Modular Architecture."

But "Modular Architecture" for organization has a difficulty to integrate information and technique in many cases. Each institute has its own information and knowledge, and some parts of those ones are the most important and valuable intellectual property. So if they have not a strong motivation to cooperate with the project team to develop their product, it is quite difficult to integrate the design knowledge in many cases.

On the other hand, "Integral" organization system has a merit to be able to have integrated information and technique, because every organization has some motivation to develop their products (in some case, they have some responsibility to collaborate to develop the products). It is necessary to integrate design information and knowledge to create a product design. Especially, construction is intricate combination of tasks, so there is a lot of design information to make a new construction system in every case. But it is difficult to have a possibility of decomposition of product system with integral product "Architecture." The basic concept of integral product "Architecture" is not to have a flexibility of elements but to create integrated total system. Although decomposition of products is the fundamental rule to make a product design, interfaces of "Integral Architecture" between elements have a complex mechanism, and the relationship between functions and parts is complicated in "Integral Architecture." "Modular" is one of the factors to promote "Open," but there are some cases that "Integral" promotes "Open Architecture." Linux, one of the operation software, is an example as this type [3]. Many capable experts have tried to create and to innovate many soft wares on this fundamental complicated operation system, and they have tried to improve this operation software for their common profit. So it is possible to have a situation that complicated system is developed as an "Modular"/"Integral" type.

5. Conclusion

In this paper, the relationship between "Open Architecture" and "Modular Architecture" is considered, and "Modular Architecture" and "Integral Architecture" in construction system are analyzed. The point of this analysis is that "Open" and "Close" are based on the information that is for construction, innovation and maintenance of system. Thus, "Open" affects "Modular Architecture" on this point. "Modular" system is recognized with modules that are connected with controlled interfaces. So it is possible to construct, innovate and maintain the system with only the information about interfaces. The number of essential information is reduced with "Modular" system, and "Modular Architecture" has a tendency to make systems "Open."

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