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RESEARCH ARTICLE

A Study of the Characteristics of Regional Building Construction Process

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Abstract:

Introduction:

In recent years, as in other fields, the architectural field has become increasingly globalized and internationalized. In this context, it is likely essential for each organization worldwide to understand how to leverage their respective strengths in internationalized projects. However, aspects of the characteristics related to how architecture is built in different regions are not fully understood.

Objective:

This study aims to develop a methodology for understanding the characteristics of architectural styles in different regions. In particular, this paper will focus on the process of building architecture and develop a methodology to understand the international differences at this point.

Methodology:

This study uses the "Architecture Concept" as the methodology. This methodology focuses on the interdependence among the components of an artifact. In this manuscript, the "building process" was considered one of the objects of this methodology. Although all construction projects take place under different conditions, it is possible to understand the tendency of design information of process design with this methodology.

Results:

This study selects regions where the building industry has reached technological maturity and compares building processes. Specifically, the UK in Europe and Japan in Asia will be compared. As a result, it is understood that the architectural process in the UK is more modular than the process in Japan. This analysis reveals that it is possible to understand the process in an "architectural" way.

Keywords: Creation process, Integration, Modularity, Design information, Process architecture, Industrial.

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1. INTRODUCTION

Technological evolution in architecture causes fundamental structural changes in social and economic systems by accelerating the interaction between people and places [1 - 4]. In other words, structural changes in these systems are evolving the way cities function. Advances in infrastructure and basic technology and the evolution of economic systems have influenced a shift in focus from industrial productivity to urban industrial diversity [5, 6].

The convergence of structural change in the built system poses complex challenges, including uncertainty, in the function of architecture [7]. It is difficult to understand the issues and envision solutions for highly complex subjects in advance. In addition, when uncertainty is involved, there is a possibility that the subject will undergo unexpected changes. Therefore, it is difficult to think in advance about how to respond to such changes. Uncertainty surrounding the complex interactions of urban functions requires tools for new problem-solving approaches by urban decision-makers [8].

Many aspects of the building industry, including construction demand, building planning philosophies, and the building construction process, including the supply chain, are changing to new systems in response to the 2020 pandemic. In particular, the idea of physical distance is being rethought, as is the difficulty of cross-country travel, remote work, and videoconferencing. As a result, work that is actually done face-to-face may be done in each region, while work that can be divided by process, such as sharing designs or producing parts, may be done across regions using videoconferencing systems. In other words, there is an aspect where the direction of construction work within a particular region and the direction

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of construction work across regions are changing simultaneously.

Under these circumstances, in order for the building industry as a whole to eliminate energy waste and realize a sustainable society, it is necessary to understand the characteristics of the building industry in each area and to indicate the direction of the future building construction system. However, since conditions in the building industry basically differ from project to project, it is difficult to have a unified discussion that is common to the entire building industry. Examples of different conditions include site conditions, surrounding environmental conditions, client requirements, and legal conditions in the area. However, discussions based on project relativities are not enough to understand the whole of the problem structure to be solved. Therefore, the purpose of this paper is to develop a methodology to describe the characteristics of the building construction process in each region.

This study aims to develop a methodology for understanding the regional specificities of the construction process that have not been discussed in previous studies. In recent years, building projects have become increasingly internationalized. If we can recognize the various regional peculiarities in the construction process, we will be able to understand how these regional peculiarities should be exploited. Recognizing this will also allow organizations in the building industry to objectively identify their strengths and weaknesses, and thus be more likely to contribute effectively to international projects. The geopolitics of the building industry after about 2023, when the pandemic is coming to an end, will be different from the geopolitics of the building industry today. Therefore, it will be important to understand its technical characteristics.

Previous research has led to a better understanding of the design information that is expressed in the composition and function of buildings [9]. Design information is also present in the building process and may have regional characteristics. This design information is the content that is created prior to the production of artifacts and is essentially created, developed, and accumulated in the designer's thinking [10]. This information is based on three fundamental aspects. They are aspects related to the function and role of the artifact, aspects related to its composition and shape, and aspects related to production methods and processes [11]. If the third of these aspects, information on production methods and processes, can be described, synergistic effects with existing research and multilayered understanding will become possible. Therefore, this study focuses on the building process.

2. THEORETICAL BACKGROUND

One of the concepts used to understand design thinking for the creation of design information is the "Architecture concept [10, 11]." This concept is capable of analyzing interdependencies between components, analyzing trends in design thinking such as the creative process of artifacts, and so on. It is based on the basic concept of the designer and on established academic methods that support technology management strategies [11]. This method helps to align investments in technical, organizational, and industrial characteristics with commercial, cultural, and social orientations [7, 10]. A framework with an elemental structure perspective supports dialogue and communication across organizational boundaries.

The basic principle of this approach is a systems concept commonly used in the design of complex engineering products [11]. This concept is based on the pattern of thinking of the creator when the artifact is created. Its logical focus is on the interdependencies among components [7]. This study uses this concept to focus on the phenomenon of the construction industry.

Researchers in many academic disciplines have attempted to describe industrial characteristics. In the field of business administration, researchers have developed sophisticated arguments based on their understanding of practical corporate activities and user-side situations. However, most of the previous studies on this architectural concept have focused on mass-produced products such as automobiles, computers, and electronic components [12 - 14].

There are two typical indicators of the architecture concept that are the modular-integral axis and the open-closed axis [11]. The modular-integral indicator is based on the interfaces between elements [11, 14]. When a system is an integral Architecture, the design rules for the interfaces must be tuned to find the optimal tuning for a particular system to maximize its potential performance [14]. In contrast, a modular architecture provides a standardized interface for linking different components or modules together [7]. Therefore, different systems can be produced by combining independent components as long as they conform to this standardized interface. The modular architecture maintains the independence of each module and accelerates the evolution of the system. On the other hand, the standardization of interfaces between modules reduces the range of performance of the overall system [14].

There are two types of modularization: open (industry level) and closed (farm level) [10, 11]. Open Architecture type is the modular architecture with industry-standard interfaces that allows the collection of components and modules across company and product boundaries. Open Architecture is based on the concept of interface generality. " In a "modular architecture" interface information can be simplified. This is the point of the relationship between modular and open indexing. The open-closed axis is extremely important but is consciously controlled by the creator. In this study, we focus on the modular-integral axis index to reveal the confusion of system functions.

System modularity has been the focus of academic attention in the last few years [14 - 16]. One of the key advantages of system modularity is its ability to provide system diversity for heterogeneous market requirements with the commonality of components [11, 17]. Although there is a clear distinction between the modularization of property and the modularization of the process [17, 18], previous studies have focused mainly on modularization as property from a static perspective [14, 15]. In addition, little attention has been paid to the modularization process of products from the maker's side. Not many industries have designed standard interfaces for process components. The advantage at this point is that products can be designed without the constraints of standards [10]. In such industries, many organizations physically modularize their products to increase competitiveness [16, 17]. However, this is difficult due to compatibility and tuning issues, and deep consideration is needed to address these issues.

The interaction between product modularization and organizational modularization has been pointed out, which is the mirroring hypothesis [19]. The main argument of this hypothesis is that modularized products are produced based on the ability of organizations to be easily modularized [20, 21]. In addition, prior research has shown that organizations design products under certain conditions, indicating that the causes of the modularization of their products are important [22, 23]. Establishing organizational modularity in R&D by reorganizing organizational units establishes interfaces and allows product modules to be compatible [24]. The organizational restructuring may be facilitated by effective organizational interfaces that provide opportunities for collaboration [25]. However, previous studies and papers have failed to explain this logically and objectively. Explanations of how effective organizational interfaces facilitate the modularization of organizations and systems are incomplete. Furthermore, the lack of a clear description of dynamic processes has hindered in-depth discussion.

Knowledge sharing can be understood as the receiving and sending of information about a task. Importantly, knowledge sharing involves collaboration to develop new processes and ideas [26]. Knowledge sharing can also have a significant impact on product development through problem-solving, willingness to assist others, and acquisition of new skills from others [27], and can be gained through communication with other professionals. This can be achieved by objectifying and documenting knowledge [27 - 30].

The relationship between organizational capacity and knowledge sharing is also an important discussion [31]. Learning can often be understood as the processing of critical knowledge. Knowledge-sharing behavior can be the basis of organizational capability [32]. Knowledge sharing can increase organizational capacity through knowledge creation and transfer, allowing designers and engineers to maintain learning capabilities throughout the organization and develop the organizational capability for practical decision-making.

Organizational capability plays an important role in acquiring the ability to respond to changes in the external environment [33]. Organizational capabilities are also important for acquiring and maintaining continuous advantage in business development Interorganizational interfaces are media or platforms that can interact, connect, and coordinate with the organizational units that border them [34]. Tangible and intangible organizational interfaces are designed to facilitate interaction and coordination [35]. However, these studies have not analyzed the combination of factors that form effective organizational interfaces. The combination of factors in organizational interfaces may affect the modularity of the organization, and thus the modularity of the system, and should be investigated and studied.

It is possible to recognize the importance of the modularity process of the system. Its complexity is based on contingencies, and the process may affect the level of modularity of the system [10, 11]. The process is very difficult to fully understand because it involves both technical and organizational elements such as interactions between different organizations [36]. As a study of the construction industry, it is possible to find out the study of projects of architecture with modular structures [37]. It has been argued that modular construction has the potential to reduce project complexity, engineering development time, and cost, and increase construction productivity. However, project characteristics and individual technologies are also discussed. Specifically, some previous studies have discussed the technical possibilities from a mass customization perspective [38] and others have considered the practical application of interfaces [39]. Most of these studies were aimed at reducing complexity in the construction industry.

This study presents ideas to understand the regional characteristics of the construction industry from the perspective of the construction concept of modularity and integration. The complexity of the construction industry, the large number of components, and the breadth of related technical fields indicate that it needs to be considered more carefully than other industries. Each project was undertaken under its own set of conditions. With these in mind, this study attempts to understand regional characteristics based on the construction concept of the construction industry, which has rarely been studied. In addition, despite the importance of the generative process, it has been difficult to fully clarify this process in previous studies. However, this study believes that understanding the characteristics of this generative process is quite important in clarifying the characteristics of construction technology in each region. Therefore, in this study, we devised a survey method and attempted to understand the characteristics of the processes related to construction technology.

The fundamental process by which a designer creates an artifact is based on the following ideas. First, the designer tries to understand the main requirements of what he or she is creating. Next, he or she comes up with a concept and organizes several key functions to realize it. Next, they relate these bundles of functions to physical elements and consider the configuration of the target product [40]. At the same time, the designer consistently designs the interfaces between each target element to correspond to the required functions [11, 14]. In other words, they create a functional group, relate the functional group to the structural group, and assemble the target group. Given the difficulty of inventing each element, it is important to design the interfaces between elements [14, 41].

This process is not one-way but is created by the creator through repeated feedback between functional design and configuration design. If the designer takes decisions based on certain tendencies while receiving a certain amount of feedback, the finished product is likely to reflect the creator's ideas [10, 42]. In prior research, such a basic design concept based on interdependencies between components related to functional group design and configuration group design is called “product Architecture” [10, 11]. In general, as mentioned above, two parameters are indicated: the open/close axis and the integral/module axis. Of these, the open/closed axis is consciously controlled by the creator, while the integral and modular axes are unknowingly manifested in the tendency to think. Therefore, without prior knowledge of the architectural concept, it is difficult for the designer to recognize them. The maker's conscious choice of open or closed refers to whether or not to select industry-standard components or standard specifications as the concrete product. However, the integral and modular axes do not allow for the specification of a uniform screening method. Designers may not be able to clearly identify the trends in their thinking. Previous studies have used “product Architecture” to discuss regional differences in building technology.

In this study, we focused on “process Architecture.” process Architecture” focuses on the composition of the architectural process and not on the composition of the built product. Designers and engineers design the configuration of the process in the same way as they design the configuration of the product. Since the process composition is also designed based on the design concept, the same argument can be made as the argument of regionality in “product Architecture” [9]. In the next chapter, “Process Architecture” is discussed for Architectures constructed based on projects. Thus, the project-based production process will be discussed, and “Process Architecture” in the building industry will be examined. This discussion will help in understanding the characteristics of the new regional aspects of architectural technology.

3. MATERIALS AND METHODS

As described above, this study discusses the modular and integral axes. These two types of design thinking can be analyzed as follows. The integral type integrates multiple system elements to develop their overall performance and is suitable for customization based on the reduction of production cost and time [11, 14] by combining standard elements [11, 18]. This point is important to understand for almost all industrial sectors, although a detailed discussion of specific industrial sectors is reserved for another time. If all firms in a particular region tend to use an integral thinking approach, then that region can dominate the market for integral products and tailor-made designs [11, 42]. Similarly, if nearly all firms in a given region adopt a modular approach, that region can dominate the market for easily interchangeable, product-compatible, open-source designs [11, 14]. Tables **1** and **2** illustrate important aspects of this argument.

In some respects, the integral type is not a disadvantage for simple, small-scale projects. Since the integral type is based on repeated fine-tuning for the entire project, it is advantageous in ensuring good performance for the project as a whole [42]. It may also be advantageous in the production and reproduction phases, depending on the characteristics of the project. In particular, project management development based on integral design thinking is typical in the low maturity stage of a project, since there is little knowledge of how to divide modules [18].

Here, a case study was conducted to compare the two areas using this architectural approach. Cases were selected for which research results were available. Specifically, we compared architectural technology in the UK and Japan. The case studies were conducted in these two regions to avoid the influence of technology, commerce, and customs from other regions. These two regions are geographically separated from the rest of the world by an ocean and have unique languages and social customs, clear legal and regulatory boundaries, and factors that make them independent from the rest of the world in many ways. Therefore, this study conducted a case study on the description of construction technology characteristics for the UK and Japan.

However, as mentioned earlier, every construction project is based on unique conditions (purpose, primary use, client requirements, site conditions, *etc.*). Therefore, it is difficult to describe the characteristics of each area by comparing construction projects. Furthermore, since buildings are composed of many components and parts, it is difficult to identify trends in construction technology. In other words, it is difficult to determine trends in construction technology because each building has its uniqueness and is composed of many elements based on different technologies.

The building design process is designed to accommodate the characteristics of a large number of elements. That is, unless there are special requirements or conditions, many organizations in the same region share the typical detailed ideas about a building. This is important when planning a project in order to obtain as accurate a budget and construction schedule as possible. However, designers working in the same region are not always easily aware that their thinking differs from that of other regions. However, it may be possible to identify technical trends through a careful understanding of architectural construction design methods.

In this study, we focused on the architectural production processes established in each region. For this reason, this study focused on the architectural production process established in each region. Process management of the construction projects requires the control of many elements. Examples of elements include challenges involving many types of technical knowledge, participation of many subcontracting organizations, and frequent uncertainties. In addition, every construction project requires process control based on the unique conditions of each project. Managers must understand all of these factors and provide the necessary direction. Therefore, the overall construction process will have different characteristics from project to project, depending on the manager's decision. If the tendency of the manager's way of thinking differs from region to region, then comparing the interdependence of the components of the process may help us understand the characteristics of each region. In particular, it may be possible to understand the characteristics of each region by comparing the interdependencies of the components of the process.

When constructing a building, it is necessary to design a construction plan. In this case, it is possible to discuss the concept of modularization and integration, which is essentially the same as the design regarding building configuration [43, 44]. Therefore, it is important to understand the status of modularization and integration of processes in construction planning.

The subject of this study is not a large uncertainty, such as a future forecast, but a subject with small uncertainties based on the perceived current state of the industry. Therefore, it is assumed that a knowledgeable and free-from-misunderstanding survey would yield accurate results. However, this survey required specialized knowledge of two specific regions. In addition, practical knowledge based on practical experience is important because it is not certain that a theoretical organization can accurately identify the subject matter. Therefore, this study required the cooperation of experts with experience as field supervisors in construction projects in both regions. However, only a limited number of experts fulfill this requirement.

The survey was conducted based on the necessary findings while understanding the particularities of each construction project through this perspective. The content of the survey was divided into several phases, carefully reflecting the considerations made thus far. The specific content of the survey, for each of these phases, is as follows.

First, 10 site supervisors with more than 10 years of experience were surveyed. They were site supervisors of a leading Japanese general contractor and had participated in construction projects in Japan and the UK. As for the content of the interviews, we also asked four professors who study building technology in Japan and the UK to confirm whether there were any problems after each step was completed.

Regarding the building construction process, a typical building was targeted. We asked the site manager to discuss and then select a building that met these criteria to be the de facto target of the study. The subject building is an office building, and the front street will not pose any problems for construction vehicles. It is assumed that many of the neighboring buildings are office buildings similar to the subject building. The site area is adequate and is located in an urban area. The building is a reinforced concrete structure with five floors and a total floor area of 3,000 square meters. The site managers who cooperated in this project have experienced similar projects, and these conditions were the assumptions for this survey.

4. RESULTS AND DISCUSSION

First, we sought to identify which processes have the greatest impact on the overall plan in an actual project. Therefore, we asked the site managers to summarize their opinions and categorize the construction project processes into five categories: “contract time,” “construction preparation period,” “construction period,” “change handling,” and “post-completion. We then asked them to select the main and most important processes. Fifteen processes are listed here (Table **3**). We then asked the site managers to rate the overall degree of integration of each process in Japanese and English on a 4-point scale (Table **4**). We then asked the field supervisors to rate each evaluation item and to discuss any problems or discrepancies they found. Although the degree of evaluation value is subjective, we chose a method that does not negate subjectivity. After the evaluation by the person responsible for the site, all scores were checked, the results were discussed, opinions were exchanged, and necessary revisions were made. The final content was discussed with the teachers and confirmed that there were no problems.

Table 1. Advantages of “modular architecture.”

Merits of Modularization
• ·Resources, such as costs, taken for adjustments and alignments among architectural elements can be significantly reduced in some cases.
• ·Each module's independence can be maintained and any changes to the entire system can be kept to local level.
• ·Reuse at module level is feasible.
• ·Development and innovation can focus on a modular unit.

Table 2. Advantages of “integral architecture.”

Type of Architecture	Merits of Integration
Integral Type	Setting rules for interfaces requires deep knowledge of the
	=> Always effective for unknown systems.
	Performance can be obtained
	=> Even the

Table 3. Index of the judgment of the importance of the integration process.

Index of Judgement	Point
I think it is only natural that subcontractors perform this coordination work.	3
I think it is only natural that subcontractors sometimes perform this coordination work.	2
I would expect subcontractors to make this adjustment in some special cases.	1
I don't think it's a given that a subcontractor will do this adjustment work.	0

Table 4. Important processes at the standing point of integration from the perspective of the site managers.

Main Process	Detail Process
A Contract	1 Confirmation of contract details (scope of responsibility)
	2 Confirmation of responsibility boundaries with other types of work
	3 Understanding the entire construction process
B Preparation	1 Daily report/confirmation of work progress
	2 Daily confirmation of work contents the next day
	3 Daily efforts to consider the best response method
	4 Examination of measure against delays in overall progress
	5 Examination of work improvement
C Under Construction	1 Site organization and cleaning
	2 Examination of storage and transportation plans for materials
	3 Thorough instructions for safety to workers
D Design Change	1 Examination of the best response when the design is changed
	2 Contribution to the construction process when the design is changed
E After Handover	1 Examination based on contract obligations for defects after handover
	2 Examination based on moral viewpoint with clients for defects after handover

Table 5. Degree of the importance of process integration between suppliers from the viewpoint of site managers (Japan).

		Site Managers										Average	Variance	Standard Deviation
J P		a	b	c	e	f	g	h	I	J	k			
A	1	2	2	3	2	3	3	1	3	3	1	2.30	0.61	0.85
	2	3	3	3	3	3	3	2	3	3	2	2.80	0.16	0.82
	3	3	2	3	2	3	3	1	2	3	1	2.30	0.61	0.85
B	1	3	3	3	3	3	3	3	3	3	3	3.00	0.00	0.83
	2	3	2	3	3	3	3	2	3	3	3	2.80	0.16	0.82
	3	2	2	3	3	3	2	2	3	3	3	2.60	0.24	0.79
	4	3	3	3	3	3	3	2	3	3	2	2.80	0.16	0.82
	5	2	2	3	3	3	3	3	3	3	2	2.70	0.21	0.81
C	1	3	2	3	2	3	3	2	3	3	2	2.60	0.24	0.79
	2	2	3	3	3	2	3	3	2	3	2	2.60	0.24	0.79
	3	3	2	3	3	3	2	3	3	3	3	2.80	0.16	0.82
D	1	3	3	3	3	2	2	3	2	3	2	2.60	0.24	0.79
	2	3	3	3	2	2	2	3	2	3	1	2.40	0.44	0.81
E	1	2	3	3	3	3	3	3	3	3	3	2.90	0.09	0.82
	2	2	3	3	3	2	2	3	2	3	2	2.50	0.25	0.77
Total average												2.65	0.25	0.81

The content of the survey examined the coordination of work by subcontractors participating in the construction process. Regarding the content of the questions, we asked the site managers to respond to what they thought subcontractors should naturally do during the construction process. In particular, they were asked to respond about projects in the UK and Japan. A summary of the 10 site managers for this content is shown in Tables **5** and **6** (0 to 3 points). After individual responses, all site managers were asked to review all evaluation values and discuss whether they felt any discomfort. The results showed no discrepancies. We also asked four teachers to review this process and the evaluation values and determined that there were no problems.

The difference in the 4-point scale is considered distinct. The mean of all scores is 0.88, which is higher for the Japanese project than for the UK project. The mean standard deviation is 0.25 for the Japanese project and 0.43 for the UK project. Therefore, it is unlikely that the dispersion state is large. In addition, most Japanese projects tend to be rated higher than UK projects. In other words, Japanese projects have a higher degree of integration than British projects. In particular, there were 9 out of 15 processes in which there was a difference of 1.0 or more in the average evaluation values of Japanese and British projects. In more than half of the processes, almost all project managers considered Japanese projects to be more integrated than British projects. The only element where the UK evaluation value exceeded the Japanese evaluation value was “Confirmation of the scope of self-responsibility of the contract.” However, this is consistent with the standardization of contractual conduct in construction work and is considered to be an evaluation indicator that includes aspects close to the definition of modularization and integration.

Table 6. Degree of the importance of process integration between suppliers from the viewpoint of site managers (UK).

UK		Site Managers												Standard Deviation
		a	b	c	e	f	g	h	I	J	k	Average	Variance	
	1	2	3	3	2	3	2	3	3	3	2	2.6	0.24	0.79
	2	2	3	2	2	2	2	2	2	2	2	2.1	0.09	0.62
A	3	2	**1**	2	3	2	3	2	2	2	2	2.1	0.29	0.7
	1	2	2	3	2	1	2	2	1	2	**1**	1.8	0.36	0.68
	2	3	**1**	3	2	1	2	1	1	2	2	1.8	0.56	0.76
	3	3	**1**	2	**1**	0	2	2	1	2	1	1.5	0.65	0.77
B	4	1	0	0	2	1	1	**1**	2	2	0	1	0.6	0.72
	5	2	**1**	1	3	1	2	2	1	2	1	1.6	0.44	0.69
	1	2	2	3	3	2	3	2	2	2	2	2.3	0.21	0.71
C	2	2	**1**	2	2	0	2	2	1	2	0	1.4	0.64	0.76
	3	2	3	3	3	3	3	3	3	2	2	2.7	0.21	0.81
	1	2	**1**	1	**1**	0	2	0	1	2	2	1.2	0.56	0.71
D	2	1	0	0	**1**	0	2	2	0	3	0	0.9	1.09	0.95
	1	3	3	3	3	3	3	3	2	3	3	2.9	0.09	0.82
E	2	0	0	0	**1**	2	0	**1**	1	0	1	0.6	0.44	0.61
Total Average												1.77	0.43	0.74

So far, we have discussed the construction process in general terms. Next, specific parts of the construction process were discussed. Based on the discussions among the persons in charge of the site, we asked them to extract the portions with large differences from the mean values shown in Tables **3** and **4**, assuming that the standard deviations were not extremely large. As a result, five processes (A-2, B-1, B-4, D-1, and E-2) shown in Table **7** were extracted. The specific construction areas investigated were the upper exterior wall, exterior wall openings, and exterior wall grounding areas. These are the most complex and representative parts of the construction. We then listed the main types of subcontractor work associated with these sections. We examined whether the content of the above five processes could be executed accurately, *i.e.*, whether the required level of integration was high. This is based on the hypothesis that when considering a construction plan for a complex construction part, the direction of the plan is likely to differ depending on the design philosophy of the creator. In other words, there are two possible directions: the priority of the trend toward reducing complexity, mainly through modularization, and the priority of improving performance, mainly through integration.

Table **8** shows the results of a standardized, detailed interview of the subcontractor's major construction types, focusing on the first part of “A-2 Confirmation of Responsibility Boundaries with Other Construction Types.” For each of the five major construction types, we asked the responsible persons on site about their common approach. This was evaluated individually for each of them, and the evaluation was conducted with 10 site managers. As shown in Table **3**, the higher the rating, the higher the degree of integration.

Table **9** summarizes the details of the Japanese standard around the opening for the subcontractor's main type of work for the five processes, including A-2. Column A-2 is the average of the cases in Tables **8** - **10** summarize these and compare the Japanese and English projects. In total, the Japanese projects are 51.8 and the British projects are 34.7. Since these figures represent the degree of integration required, it can be seen that the pre-and post-opening construction of Japanese projects requires a higher degree of integration than that of the UK. On average, 10.36 projects in Japan and 6.94 projects in the UK were subcontracted. Thus, looking at averages by type of subcontracted work, Japanese projects are 2.07, and UK projects are 1.39. In other words, based on a 4-point index, there is a difference of 0.68, which is a sufficient difference. As for the dispersion, the Japanese project is 0.21, while the UK project is 0.27. Thus, there were no major problems with the dispersion situation.

Tables **11** and **12** present data for the area around the foundation for projects in Japan and the UK. The same trend was observed around the openings. Therefore, the expected level of integration with respect to construction is higher in Japan than in the UK. Tables **13** and **14** also show a similar trend for data around copings. The average value is 10.54 in Japan and 8.04 in the UK.

The above data indicate that there is a relatively large variation in the evaluation of projects in the UK. This is because the value of E-2 is smaller than the others. In other words, the value of the evaluation of the UK projects is smaller for “Consideration based on the moral point of view with the customer for defects after delivery.” In other words, after delivery, subcontractors tend not to ask for moral considerations that are not specified in the contract. In Japan, however, as with other evaluation axes, subcontractors tend to respond to contents that are generally expected. This indicates that construction firms may have to do more than what is in the contract. This is not unnatural and is understandable from a different perspective. In order to commission construction work, the client must have a basic desire to obtain the building. However, many clients have little experience in commissioning construction work and rarely have sufficient knowledge. contents such as E-2 indicate that what is necessary to realize the client's desire is included as a condition. In other words, a small evaluation value of E-2 may indicate that the given conditions are not integrated.

To summarize, this section discusses three representative and complex building parts and compares the degree of integration required for construction in Japanese and English projects. From both countries' perspectives, it can be understood that Japanese projects require a higher degree of integration in the various construction processes than British projects.

Table 7. Processes that require integration.

Main Process	Detail Process
A Contract	2 Confirmation of responsibility boundaries with other types of work
B Preparation	1 Daily report/confirmation of work progress
	4 Examination of measure against delays in overall progress
D Design Change	1 Examination of the best response when the design is changed
E After Handover	2 Examination based on the moral viewpoint with clients for defects after handover

Table 8. Required integration scoring by ten site managers (left; Japan, right; UK).

Site Managers	Sash	Casing	Wall Finish	Ceiling	Sealing	Site Managers	Sash	Casing	Wall Finish	Ceiling	Sealing
a	2	3	2	1	3	a	2	2	1	1	2
b	3	3	3	3	3	b	1	1	0	0	1
c	2	3	2	2	3	c	2	2	1	1	2
d	1	2	2	1	3	d	1	1	1	1	1
e	1	3	1	1	3	e	1	2	1	2	2
f	2	2	2	2	2	f	2	1	0	1	2
g	1	3	2	2	2	g	0	1	0	1	1
h	3	3	3	3	3	h	2	2	2	2	2
i	1	2	2	2	3	i	0	0	0	0	2
j	1	2	1	1	2	l	1	1	0	1	1
Average variance	1.7	2.6	2	1.8	2.7	Average variance	1.2	1.3	0.6	1	1.6
	0.61	0.24	0.4	0.56	0.21		0.56	0.41	0.44	0.4	0.24

Table 9. Averages of scores by site managers (from Table 8, around the opening, Japan).

-	Sash	Casing	Wall Finish	Ceiling	Sealing	Total
A-2	1.7	2.6	2	1.8	2.7	-
B-1	2.4	2.2	2.2	1.9	2.5	-
B-4	2.3	2	2.2	2.5	2.1	-
D-1	2.4	1.7	1.9	2.3	2.4	-
E-2	1.2	0.9	2.5	2.3	1.1	-
Subtotal	10	9.4	10.8	10.8	10.8	51.8
Average	2	1.88	2.16	2.16	2.16	10.36
Variance	0.23	0.33	0.04	0.07	0.32	0.21

Table 10. Averages of scores by site managers (from Table 8, around the opening, UK).

-	Sash	Casing	Wall Finish	Ceiling	Sealing	Total
A-2	1.2	1.3	0.6	1.0	1.6	-
B-1	2.3	1.4	1.8	1.8	2.2	-
B-4	1.4	0.8	1.1	1.5	1.2	-
D-1	2.3	2.2	1.4	2.0	1.1	-
E-2	1.0	0.5	0.9	1.3	0.8	-
Subtotal	8.2	6.2	5.8	7.6	6.9	34.7
Average	1.64	1.24	1.16	1.52	1.38	6.94
Variance	0.31	0.34	0.17	0.13	0.23	0.27

Table 11. Averages of scores given by site managers (around the foundation, Japan).

-	Excavation	Removalof Surplus Soil	Foundation Work	Concrete Formwork	Concrete Work	Total
A-2	2.2	1.1	1.6	2.3	2.1	-
B-1	2.4	2.1	2	2.4	2.3	-
B-4	2.1	2.1	1.7	2.3	1.8	-
0-1	1.8	2	2.3	2.3	1.4	-
E-2	0.8	0.4	0.7	1.1	1.4	-
Subtotal	9.3	7.7	8.3	10.4	9	44.7
Average	1.86	1.54	1.66	2.08	1.8	8.94
Variance	0.32	0.47	0.29	0.24	0.13	0.32

Table 12. Averages of scores given by site managers (around the foundation, UK).

-	Excavation	Removalof Surplus Soil	Foundation Work	Concrete Formwork	Concrete Work	Total
A-2	1.2	0.4	1.3	1.7	1.8	-
B-1	0.8	0.9	1.5	1.8	2.0	-
B-4	2.1	1.8	1.2	1.0	1.2	-
D-1	0.4	0.2	1.4	1.9	1.5	-
E-2	0.3	0.1	0.2	0.6	0.7	-
Subtotal	4.8	3.4	5.6	7.0	7.2	28.0
Average	0.96	0.68	1.12	1.40	1.44	5.60
Variance	0.43	0.39	0.22	0.26	0.21	0.38

Table 13. Averages of scores given by site managers (around the coping, Japan).

-	Waterproof	Coping	Sealing	Down Ppipe	Ext Wall Finish	Total
A-2	2.5	2.7	2.5	2.4	2.5	-
B-1	2.4	2.5	2.2	2.1	2.3	-
B-4	2.0	1.6	1.7	1.1	2.3	-
D-1	2.5	2.6	2.1	2.0	2.4	-
E-2	2.2	1.4	1.7	1.1	1.9	-
Subtotal	11.6	10.8	10.2	8.7	11.4	52.7
Average	2.32	2.16	2.04	1.74	2.28	10.54
Variance	0.04	0.30	0.09	0.29	0.04	0.20

Table 14. Averages of scores given by site managers (around the coping, UK).

-	Waterproof	Coping	Sealing	Down Pipe	Ext Wall Finish	Total
A-2	1.9	2.3	1.7	1.6	1.5	-
B-1	20	2.2	2.3	1.7	2.3	-
B-4	2.1	2.0	1.7	2.1	1.4	-
D-1	1.9	2.1	1.4	1.9	2.1	-
E-2	0.4	0.2	0.4	0.3	0.7	-
Subtotal	8.3	8.8	7.5	7.6	8.0	40.2
Average	1.66	1.76	1.50	1.52	1.60	8.04
Variance	0.40	0.62	0.39	0.40	0.32	0.44

In this chapter, the key processes that are important to construction projects are identified and discussed in terms of their characteristics. This discussion is based on the knowledge of the experts. The approach to this discussion is based upon the thinking way that does not deny a certain subjectivity but relies on a thoughtful judgment that integrates experience and knowledge. In addition, errors due to subjectivity were checked as much as possible by statistical methods. These considerations have allowed us to understand the trends in the construction process in the two regions. Based on the differences in these trends, we are able to understand the characteristics of the construction process in each region.

Based on this understanding, it is possible to sort out the technical strengths and weaknesses of each region in the construction process. In other words, we believe that we have developed a method to describe one aspect of the technical characteristics of each region.

CONCLUSION

The purpose of this study is to develop a methodology for understanding regional differences by understanding the process by which architecture is constructed. In particular, we developed a methodology to describe the characteristics of “process Architecture” by focusing on the composition of the production process. Because the conditions of architecture vary from project to project, simple comparisons are difficult to make. However, it is possible to look for a shared perspective and try to understand the characteristics of the process from that perspective. Using this method, we described the design information of the production process in architectural projects in the UK. and Japan and ascertained its strengths and weaknesses.

From these results, we were able to confirm that the trend of design information for “product Architecture” in the previous study [9] coincides with that of “process Architecture” in this study. In other words, the design information of “product Architecture” in the UK and Japan and the design information of “process Architecture” in this study show the same trend. Design information is considered to reflect the tendency of the creator of the information to think in a certain way. The previous study focused on the physical composition of the production process and analyzed the resulting architectural form [9]. This study focused on the composition of the production process and analyzed a different target than the previous study. These two studies are based on the same perspective in that they analyze the target in which the tendency of the maker's thinking is expressed. This result suggests the possibility of capturing the characteristics of organizations in each region in a multilayered manner. Understanding these characteristics would increase the likelihood of developing a precise strategy for each project. In addition, the possibility has emerged that clients can select and place orders with organizations that possess the strengths necessary for their projects. In other words, depending on the characteristics of the project, such as whether cost or quality is a priority, it may be possible to make decisions that are compatible with the factors to be prioritized.

In an organization that mainly uses a modular design approach to technology development and product design, the process of creation is considered to proceed by modularizing the relevant elements. This indicates that a given node is divided into chunks to create products, services, systems, information, processes, concepts, and so on. These nodes include information, knowledge, components, materials, *etc*.

The process configurations covered in this paper can be discussed in the same way as other product and system configurations. In organizations, process configurations are modularized based on the concept of modular design. In such an organization, the project proceeds by dividing the entire process into chunks. In other words, they create modularized processes. In this case, the person responsible for a process module proceeds while considering only that module.

Conversely, in an organization based on an integral-type design philosophy, processes are also integralized. In other words, in such an organization, processes are not modularized but fully integrated. Instead of considering each process in isolation, the project is carried out with an emphasis on the interrelationships among multiple processes. In this case, it is possible to improve various aspects of construction performance, such as work within the construction period and overall quality. However, every process requires a considerable amount of labor. In addition, each process tends to be costly.

However, as representative examples, we take here office buildings in the UK and Japan. Although the

methodology has been established, it is necessary to understand and systematize the trends of design information related to the process in each region. Therefore, it is necessary to scrutinize design information in each region and accumulate data. In addition, although office buildings were the subject of this study, it is also necessary to examine trends in design information for buildings of other major uses, such as residences and factories. For these purposes, this study will be continued.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The data and supportive information are available within the article.

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CONFLICT OF INTEREST

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