A Comparative Study of the Design Process in General Construction Companies and Design Firms in Japan

Masatoyo Ogasawara*1 and Tomonari Yashiro2

1Lecturer, Department of Architecture, School of Science and Technology for Future Life, Tokyo Denki University, Japan
2Professor, Institute of Industrial Science, the University of Tokyo, Japan

Abstract
This paper aims to illustrate the design review process of "General Construction Companies" (GCCs) and "Design Firms" (DFs) in Japan. It then quantitatively evaluates the time duration for the production of "design and supportive documents" which is required to go through a design review.

The research is divided into three stages. First, the constraints in the design process in both GCCs and DFs are illustrated. Second, the duration of each design phase is measured to assess the allocation of resources for design coordination required by the constraints. Third, the most commonly shared building types in the survey were evaluated based on the "designed floor area per month."

The survey statistically confirms the characteristics of the front-loaded design process by GCCs in the Preliminary Design phase to the Detailed Design Phase. GCCs have more cost and time constraints than DFs, through the involvement of the Cost Estimation and Procurement division in the construction department. It requires the production of "design and supportive documents" throughout the design process. On the contrary, DFs tend to spend more time and resources in the later part of the design process. This grants DFs more flexibility in cost and time throughout the design process as they have less strict constraints than GCCs.

Keywords: design process; design review; constraints; Design-Build

1. Introduction
In Japan, "General Construction Companies" (GCCs) and "Design Firms" (DFs) are the two dominant players in designing large and complex buildings. These organizations employ experienced in-house specialists, such as architects, engineers, cost estimation, and quality assurance experts. Both GCCs and DFs accumulate a vast amount of information and knowledge from their prior projects. Both GCCs and DFs organize internal design reviews several times during the design process, in which specialists evaluate the compatibility to the constraints. The posed constraints eventually shape the final design outcome.

Though its importance is widely recognized by the architectural community, this design review process has not been thoroughly surveyed in Japan. With a focus on GCCs and DFs, this paper aims to illustrate the design review process of both organizations, and then quantitatively evaluates the time duration for the production of "design and supportive documents" which is required to go through a design review.

2. Literature Review
Japan has a long tradition of master builders. They are in charge of both design and construction in woodwork (Nagai 1982; Frampton and Kudo 1997). It is believed that Japanese clients prefer to have a single point of responsibility (Sjoholt 1999). As a result, Design-Build has been a well-received project delivery method in Japan. For example, Takenaka Corporation, one of the big five general contractors, earned approximately three-quarters of their annual revenue through the Design-Build in the first half of year 2014 (Nikkei BP 2014). Design-Build has either a contractor-led or a designer-led approach (Stark and Perkins 2003). In Japan, the contractor-led approach is far more common than the designer-led approach due to technical and financial capabilities assured by the general contractors (Eguchi 1982; Oguro 2007).

Design-Build has both advantages and limitations. The advantages are shortening of lead times, assuring the construction feasibility, greater price certainty, improved communication, and reduced construction time, among others (Anumba and Evbuomwan 1997). Conversely, the limitations are reduced quality of
materials and workmanship because of the contractor's incentive to complete projects faster and less expensively, and the clients' less control of the design because A/E represents the contractors' best interests (Cudney 2006). However, there are differences in opinion between contractors and designers regarding the use of Design-Build. While contractors state the quality of design documents in Design-Build was higher than those in Design-Bid-Build, the designers considered otherwise (Andi and Minato 2003). A survey of architects shows that product quality and design innovation generally suffers in Design-Build (Akintoye and Fitzgerald 1995). Due to the difficulty of construction cost management after the Great East Japan Earthquake in 2011, Design-Build has become popular in Japan more than ever. Distinctions in the design process between GCCs and DFs, however, have not been quantitatively researched up to this point.

In Japan, Design-Build is conducted mainly by GCCs, which have in-house architects, and engineers. The organizational structure of GCCs enables them to start an intensive design review process prior to the design contract. In Design-Build in the US, however, contractors typically hire architects as consultants for design services (AIA 2014). It is fair to say that, compared to Japan, the involvement of architects happens later.

Regardless of the project delivery method, whether Design-Build or Design-Bid-Build, internal design reviews are executed both in GCCs and DFs to confirm the compatibility to the constraints. Constraints are limiting factors that affect the execution of a project or process (Project Management Institute 2013). Constraints may be posed by legislators, users, clients, and designers, but with different degrees of rigidity (Lawson 2006). In large projects, the control gateways are arranged within stages to reflect the approval of key work packages (Emmitt 2014).

The significance of constraints has been noted by many researchers, but the pragmatic application of constraints in Japanese projects has not been thoroughly researched yet. In this paper, the authors focus on the application of constraints in the design review process to evaluate the differences between GCCs and DFs.

3. Research Methodology

3.1 Subject of Investigation: GCCs and DFs

This paper focuses on the design process managed by a single organization. Either the design process of Design-Build projects by GCCs, or Design-Bid-Build projects by DFs are considered. The design collaboration between GCCs and DFs in the middle of the design process, such as "Bridging" type of Design-Build project delivery method, is excluded.

As for GCCs, the big five general construction companies – Shimizu Corporation (Shimizu), Obayashi Corporation (Obayashi), Taisei Corporation (Taisei), Takenaka Corporation (Takenaka), and Kajima Corporation (Kajima) – are selected (Table 1.). A GCC is composed of many departments and divisions, but the main functions are divided into four major departments: Management, Design, Construction, and R&D.

The Architects Act in Japan, effective in 1950, provides licenses to those who have sufficient technical knowledge and experience in construction. Therefore, not only architects but also builders hold qualified architect's licenses. In Table 1., the number of qualified first class architects is indicated. In Obayashi, Takenaka, and Kajima, the number of license holders is more than 2,000. Due to the unavailability of official data, the number of employees in the design department is obtained through in-person interviews.

Table 1. Big Five General Construction Companies (2014)

| Company       | Shimizu | Obayashi | Taisei | Takenaka | Kajima |
|---------------|---------|----------|--------|----------|--------|
| Annual Revenue (Million Yen) | 1,047,270 | 958,646  | 886,194 | 842,411  | 780,841 |
| Established   | 1804    | 1892     | 1873   | 1610     | 1840   |
| Employees (total) | 10,547  | 9,430    | 8,006  | 7,282    | 9,422  |
| Qualified First Class Architects | Unknown | 2,129    | Unknown | 2,574    | 2,225  |
| Employees in the design department | 800     | 750      | 600    | 1,150    | 500    |

Note: Data of the annual revenue, the number of employees, and the number of qualified first class architects are adapted from the 2014 survey by Nikkei Architecture (Nikkei 2015). The established year is referred to on the companies' website.

Table 2. Large Design Firms (2014)

| Company       | Nikken Sekkei | NTT Facilities | Nihon Sekkei | Mitsubishi Jisho Sekkei | Kume Sekkei |
|---------------|---------------|----------------|--------------|-------------------------|-------------|
| Annual Revenue (Million Yen) | 32,924        | 28,232         | 15,633       | 15,501                  | 10,213      |
| Established   | 1950          | 1992           | 1967         | 2001                    | 1932        |
| Employees (total) | 1,760        | 5,500          | 846          | 576                     | 592         |
| Qualified First Class Architects | 800          | 700            | 444          | 316                     | 328         |

Note: Data of the annual revenue, the number of employees, and the number of qualified first class architects are adapted from the 2014 survey by Nikkei Architecture (Nikkei 2015). The established year is referred to on the companies' website.
As for DFs, the top five companies in terms of annual revenue in the year 2014 – Nikken Sekkei Ltd. (Nikken Sekkei), NTT Facilities, Inc. (NTT Facilities), Nihon Sekkei, Inc. (Nihon Sekkei), Mitsubishi Jisho Sekkei, Inc. (Mitsubishi Jisho Sekkei), and Kume Sekkei, Co., Ltd. (Kume Sekkei) – are selected (Table 2.). In contrast to a GCC, a DF is composed of just two major departments: Management and Design.

Small-sized design firms are excluded from this research. In designing large and complex buildings, these firms have to form an ad-hoc design consortium with consultants because they have a limited number of internal specialists. Their design process is considered less structured than GCCs and DFs, which have a routine design review process to design large and complex buildings in the shortest possible time frame.

3.2 Methodology

The research is divided into three stages. First, the constraints in the design process in both GCCs and DFs are illustrated. Architects and engineers must go through design reviews in the General Planning Phase (Kihon Keiikaku), Preliminary Design Phase (Kihon Sekkei), and Detailed Design Phase (Jisshi Sekkei). In the design review, the specialists evaluate the current design based on the constraints. In-person and e-mail interviews are conducted to confirm the details of these design reviews. Time, Cost, and Quality are the categories utilized to measure the success of projects in some papers (Baccarini 1999; Brown and Adams 2000). These three categories are applied for evaluation in this paper.

Second, the duration of each design phase is measured to assess the allocation of resources for design coordination required by the constraints. The duration is then converted to its percentage in the total design duration. It is based on the assumption that the time allocated in the design process dictates the design outcomes. Basically, both GCCs and DFs try to minimize the production of design documents to reduce the labor cost of the design department. However, the specific design phase inevitably requires a longer time than the other phases to coordinate more intensive design reviews and ensuing production.

Five GCCs and five DFs (Table 1. and Table 2.) are surveyed from July to December 2015. The interviewed architects are full-time employees who explained their respective organization's design review process and the allocation of design phases. In total, eight in-person interviews and three e-mail interviews are conducted with GCCs, and 12 in-person interviews are conducted with DFs.

Third, the most commonly shared building types in the survey were evaluated based on the "designed floor area per month."
4.1.1 Time
In both GCCs and DFs, the rough construction schedule is estimated based on the experience of prior projects. Conventional office and residential projects in urban areas are relatively smoothly evaluated. However, some projects have uncertainty, due to factors such as unique site conditions, unconventional structural systems, and inflexible labor conditions. While DFs must seek outside resources for the information to clarify the uncertainty, GCCs can obtain the latest information from their construction department internally.

The Construction Planning information is updated as design progresses in GCCs and DFs. The survey confirmed that the involvement of the Construction Supervision division and the Procurement division in GCCs assured the feasibility of the actual construction, especially in preparation works and the delivery time for construction materials. The early involvement of the construction specialists in the design process prevents the time-consuming process of coordinating construction methods and schedule, especially at the early stage of construction, when the design information is handed from the Design department to the Construction department. Detailed design documents without feasible construction planning information cause a constant reevaluation of the documentation during the construction phase, which makes project delivery time lengthier than in the case of well-evaluated documents. Therefore, GCCs have an advantage concerning Time constraint.

4.1.2 Cost
In both GCCs and DFs, the cost of the design content is evaluated by the Cost Estimation division. They estimate the cost by referring to the monthly publication "Construction and Material Cost (Gekkan Kensetsu Bukka 2016)" in addition to their previous projects' estimation history. The Procurement division's involvement in the Cost Estimation division is what makes GCCs significantly different from DFs. When the material price and labor cost are unpredictable, it is essential to obtain the latest local-specific information from the Procurement division.

In a GCC, the maximum construction price is fixed upon acceptance of the General Planning proposal. The contract price will be adjusted, if necessary, at the end of the Detailed Design phase before construction. The Procurement Plan, which secures the profit of the GCC, starts to be evaluated in the Preliminary Design phase. The GCC prepares and evaluates the design thoroughly at this early phase. This front-loaded design process makes the estimation feasible, but it also forces the GCC to have detailed design under strong cost constraints.
Conversely, a DF has more flexibility in design until the Detailed Design phase. The final construction cost is under competition in the tender. The cost competition gives advantages to the client. However, the design process makes cost control difficult, especially when the workers' labor conditions are unstable.

The client may not prepare an elaborated project brief as they expect design decisions are to be made during the Preliminary Design and Detailed Design phase. It sometimes happens that clients figure out what they really want to achieve as the design progresses with the input of architects and engineers. Flexibility in the cost constraint helps to meet clients' constant demand changes.

4.1.3 Quality

Both GCCs and DFs set their companies' own design criteria based on their previous projects. They distribute typical detail sheets and specifications internally as a reference. The Quality Assurance division checks design documents, especially when the contract documents are issued. For this purpose, well-experienced architects and engineers are allocated to the division.

In a GCC, the various types of construction-related information are obtained through on-site construction supervision. The liability related information, such as leaking and cracking, are collected and passed along to the Quality Assurance division and shared internally. Moreover, a GCC has its own Research and Development department, which not only helps to solve technical problems but also involves leading-edge research and lets innovation take place (Bennett 1993; Haley 1994). These capabilities indicate the advantage of the GCC. They have access to broader and more detailed construction-related information, which is not easily obtained by a DF or other smaller general construction companies.

A close relationship between design and construction is not always considered preferable. A GCC has an exclusive collaboration with subcontractors, fabricators, and suppliers. This tightly formed collaboration has a beneficial effect on the cost and the performance of their suppliers, though the same relationship may constrict the application of the materials and method of construction. This may limit the design-creative capacity. More than half of the interviewees in the GCCs design department admitted that the constraints from the construction department pressured them to reduce design-creative capacity.

The measurable requirements of a building can be described in the project brief, but the subjective quality may be hard to clarify. The cost constraint at the early phase may sacrifice the quality of materials and workmanship of the building by a GCC. An interviewee made a point using the example of the storefront. Both aluminum and stainless steel are weather-resistant materials and an optimal choice for storefronts in Japan. Despite their similar functionality, a GCC places significant preference for aluminum over stainless steel because of the cost. It is difficult for clients to specify the material details in the General Planning package. The clients' strong aesthetic preference for stainless steel should be described in the project brief. Otherwise, storefronts inevitably will be constructed in aluminum in Design-Build projects.

Different building types require different priorities in Cost, Time, and Quality. All interviewees in GCCs and DFs share this viewpoint. For example, production facilities, such as factories and storage centers, require a relatively higher prioritization of Cost and Time. Monumental facilities, such as museums and city halls, require a relatively higher prioritization of Quality. It is difficult to establish the mutually understood criteria of Quality, but Cost and Time can be evaluated objectively.

Some GCCs form a special design team for production facilities, for which Cost and Time do matter. By offering an integrated design/construction service in production facility projects, the design team successfully emphasizes the advantage of Design-Build.

4.2 The Duration of Design Phases

The duration of each design phase is measured and converted to its percentage in the total design duration. In the survey, the number of the projects is limited to four per organization. Each interviewee can provide only one or two projects. The tender period is counted as part of the Detailed Design phase. Projects with a total floor area of between 1,000 sqm and 50,000 sqm are collected, in order to focus on the typical size of the architectural projects by GCCs and DFs. Urban redevelopment projects, which require an extended amount of time for negotiation of neighbors and legal approval, are excluded. From GCCs, 16 project details are obtained by eight in-person and three e-mail interviews (Table 3.). From DFs, 16 project details are obtained by 12 in-person interviews (Table 4.).

The duration of design phases is compared between GCC and DF projects in Fig.3. The more design documents are required, the longer production time is expected. The figure indicates that GCCs are inclined to have a front-loaded design process. The figure confirms the interviews that the Preliminary Design phases are long enough to go through the intensive design reviews and following updates. The Detailed Design phase is purely for documentation purposes for internal use for construction.

In a GCC, the second Rough Estimation and the initial Procurement Plan are arranged in the Preliminary Design phase (Fig.1.). Architects and engineers have to make significant efforts to prepare documents for the estimation. An interviewee stated that they produced almost double the amount of supplementary documents compared to the volume of drawings in this phase. The supplementary documents are passed onto the Cost Estimation and Procurement
### Table 3. The Duration in Each Design Phase: GCCs

| Project Number | Building Type | Area Square Meters | General Planning | Preliminary Design | Detailed Design |
|----------------|---------------|-------------------|------------------|-------------------|-----------------|
|                |               | General Planning  | Preliminary Design | Detailed Design |
|                |               | % Month           | % Month           | % Month           |
| 1              | School        | 5,700             | 4.0              | 28.6             | 4.0             | 28.6            | 6.0             | 42.8            |
| 2              | School        | 2,600             | 2.0              | 33.3             | 1.0             | 16.7           | 3.0             | 50.0            |
| 3              | Hall          | 4,370             | 6.0              | 26.1             | 8.0             | 34.8           | 9.0             | 39.1            |
| 4              | Hospital      | 20,800            | 5.0              | 22.7             | 10.0            | 45.5           | 7.0             | 31.8            |
| 5              | Hospital      | 30,250            | 4.0              | 22.2             | 8.0             | 44.4           | 6.0             | 13.3            |
| 6              | Laboratory    | 7,500             | 5.0              | 45.4             | 3.0             | 27.3           | 3.0             | 27.3            |
| 7              | School        | 15,150            | 3.0              | 25.0             | 4.0             | 33.3           | 5.0             | 41.7            |
| 8              | School        | 26,000            | 2.0              | 11.8             | 7.0             | 41.2           | 8.0             | 47.0            |
| 9              | School        | 12,300            | 2.0              | 15.4             | 5.0             | 38.5           | 6.0             | 46.1            |
| 10             | Laboratory    | 7,000             | 12.0             | 50.0             | 6.0             | 25.0           | 6.0             | 25.0            |
| 11             | School        | 7,000             | 4.0              | 33.3             | 4.0             | 33.3           | 4.0             | 33.3            |
| 12             | Housing       | 4,700             | 1.3              | 17.7             | 5.0             | 58.8           | 2.0             | 22.5            |
| 13             | Laboratory    | 22,500            | 0.3              | 3.6              | 5.0             | 60.2           | 3.0             | 36.1            |
| 14             | Laboratory    | 2,500             | 2.0              | 28.6             | 3.0             | 42.8           | 2.0             | 28.6            |
| 15             | Laboratory    | 13,000            | 3.0              | 28.6             | 5.0             | 47.6           | 2.5             | 23.8            |
| 16             | Office        | 8,000             | 3.0              | 30.0             | 3.0             | 30.0           | 4.0             | 40.0            |
| Average        |               | 11,836            | 3.7              | 26.4             | 5.1             | 38.0           | 4.8             | 35.6            |

### Table 4. The Duration in Each Design Phase: DFs

| Project Number | Building Type | Area Square Meters | General Planning | Preliminary Design | Detailed Design |
|----------------|---------------|-------------------|------------------|-------------------|-----------------|
|                |               | General Planning  | Preliminary Design | Detailed Design |
|                |               | % Month           | % Month           | % Month           |
| 1              | Office        | 4,000             | 0.5              | 9.1              | 1.0             | 18.2           | 4.0             | 72.7            |
| 2              | Laboratory    | 7,000             | 2.0              | 15.4             | 3.0             | 23.1           | 8.0             | 61.5            |
| 3              | Office        | 8,000             | 6.0              | 37.5             | 4.0             | 0.3            | 6.0             | 37.5            |
| 4              | Museum        | 2,600             | 3.0              | 17.6             | 3.0             | 17.6           | 11.0            | 64.7            |
| 5              | Laboratory    | 6,700             | 8.0              | 32.0             | 6.0             | 24.0           | 1.0             | 44.0            |
| 6              | Office        | 9,500             | 2.8              | 41.2             | 2.0             | 29.4           | 2.0             | 29.4            |
| 7              | Office        | 12,000            | 3.0              | 33.3             | 3.0             | 33.3           | 3.0             | 33.3            |
| 8              | School        | 32,000            | 4.0              | 30.8             | 4.0             | 30.8           | 5.0             | 38.5            |
| 9              | School        | 15,000            | 2.5              | 29.4             | 3.0             | 35.3           | 3.0             | 35.3            |
| 10             | Office        | 7,000             | 1.5              | 16.7             | 2.0             | 21.1           | 6.0             | 63.2            |
| 11             | Theater       | 7,000             | 0.5              | 14.3             | 1.0             | 28.6           | 2.0             | 57.1            |
| 12             | School        | 9,690             | 4.0              | 21.1             | 8.0             | 42.1           | 7.0             | 36.8            |
| 13             | Library       | 10,850            | 3.0              | 21.4             | 5.0             | 53.7           | 6.0             | 42.2            |
| 14             | School        | 3,500             | 0.5              | 4.2              | 7.0             | 58.3           | 4.5             | 37.5            |
| 15             | School        | 13,000            | 2.0              | 11.8             | 7.0             | 41.2           | 8.0             | 47.0            |
| 16             | School        | 8,000             | 1.0              | 10.0             | 4.0             | 40.0           | 5.0             | 50.0            |
| Average        |               | 9,740             | 2.8              | 22.5             | 3.9             | 31.5           | 5.7             | 46.0            |

Fig. 3. Comparison in the Duration of Design Phases

### 4.3 Production in Design Phases

The results show that, comparing the same time duration, the GCCs design less floor area than the DFs. A GCC does not necessarily produce more design documents for estimate and procurement, than "design and supportive documents", such as additional "design and supportive documents" in all surveyed projects, "designed floor area per month" is utilized as a measurement.

In GCCs, six school projects are reviewed. On average, monthly, 4,779 square meters are designed in the General Planning phase, 2,623 square meters are designed in the Preliminary Design phase, and 1,983 square meters are designed in the Detailed Design phase (Table 5.).

In DFs, six school projects are reviewed. On average, monthly, 3,620 square meters are designed in the General Planning phase, 3,095 square meters are designed in the Preliminary Design phase, and 2,798 square meters are designed in the Detailed Design phase (Table 6.).

The results show that, comparing the same time duration, the GCCs design less floor area than the DFs. It is interpreted that the GCCs produce more "design and supportive documents" such as additional design documents for estimate and procurement, than the DFs throughout the project. The results support divisions to collect estimations from subcontractors and/or distributors for the project.

In contrast, the duration of the later part of the design process has drastically increased in DFs. The Detailed Design phase takes approximately 1.5 times longer than the Preliminary Design phase. Detailed design documents are prepared for tender. The responsibility among the architects and the contractors should be clearly divided and indicated in the tender documents. Several interviewees pointed out that the Detailed Design documents by a DF tend to be more detailed than those of a GCC. A GCC does not necessarily emphasize the clear division of responsibility between design and construction departments.
Table 6. Designed Floor Area per Month School Projects in DFs

| Project Number | Building Type | Area Designed Square Meters | General Planning Months | Preliminary Design Months | Detailed Design Months | Average Designed Floor Area per Month |
|----------------|---------------|-----------------------------|-------------------------|--------------------------|------------------------|---------------------------------------|
| 1              | School        | 5,700                       | 4.0                     | 1,425                    | 4.0                    | 1,425                                 |
| 2              | School        | 2,600                       | 2.0                     | 1,300                    | 1.0                    | 2,600                                 |
| 7              | School        | 15,150                      | 3.0                     | 5,050                    | 4.0                    | 15,150                                |
| 8              | School        | 26,000                      | 2.0                     | 13,000                   | 7.0                    | 26,000                                |
| 9              | School        | 12,300                      | 2.0                     | 6,150                    | 5.0                    | 12,300                                |
| 11             | School        | 7,000                       | 4.0                     | 1,750                    | 4.0                    | 7,000                                 |
| Average        |               |                             |                         |                          |                        | 11,458                                |

Fig.4. Comparison of the Designed Floor Area per Month in School Projects

the survey that the tighter Cost and Time constraints enforced extra effort for the production of "design and supportive documents" to GCCs (Fig.4.). It assures them of the construction Cost and Time especially in the following construction phase.

5. Conclusions

This paper illustrates the design review process of both organizations, and then quantitatively evaluates the time duration for the production of "design and supportive documents" which is required to go through a design review. It clarifies the differences of the design process between GCCs and DFs in Japan. The constraints characterize the differences in the design process. The evaluations follow:

<The characteristics of the design process in GCCs>
1. The characteristics of the front-loaded design process by GCCs are statistically confirmed in the Preliminary Design phase to Detailed Design Phase.
2. GCCs have more cost and time constraints than DFs, through the involvement of the Cost Estimation and Procurement division in the construction department. It requires the production of "design and supportive documents" throughout the design process.

<The characteristics of the design process in DFs>
1. DFs tend to spend more time and resources in the later part of the design process.
2. DFs are more flexible in cost and time throughout the design process as they have less strict constraints than GCCs.

The authors illustrated the design review process in Fig.1. and Fig.2., which had not been thoroughly surveyed in Japan. They then quantitatively evaluated the time duration for the production of "design and supportive documents", which is required to go through a design review.

The authors evaluated the design review process with "time duration." More detailed quantitative evaluation of the design review is expected in future research.

In Japan, the design contents of the Detailed Design documents tend to be constantly updated on site in the shop drawing approval process. The design process in the construction phase, such as the details of change orders, should be researched further.

Cost and time can be defined objectively. Quality, however, is hard to evaluate objectively. The quality measurement process awaits further investigation.

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