MANAGEMENT OF INNOVATION TO ENHANCE THE SAFETY DESIGN IN TALL BUILDING PROJECTS

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Abstract
This is an ongoing research which aims to propose alternative solutions on management of making new technologies and innovations on the safety design of tall buildings. This paper examines the key ideas by presenting tall building project case studies from Japan and makes comparisons with overseas cases. The investigation focus of the case studies is, basically, to determine the "physical & organizational vulnerabilities" through the analysis of the management of knowledge during the project life-time. This paper briefly: 1) Describes the origins of knowledge management through the process of innovation management. 2) Defines the physical and organizational vulnerabilities of tall building projects and the necessities of innovations. 3) Points out the importance of code-plus-performance analysis based safety designs in relation to the knowledge and technology fusion aspects. 4) Discusses the sufficient combination of explicit and implicit codes used within the technology and knowledge acquisition process. 5) Identifies the critical issue of intelligent building automation systems to improve building safety. 6) Puts forth the most common policies which exist in Japanese and international organizations for developing innovation through case studies on tall building projects.

Keywords: Tall buildings, Physical and organizational robustness, Performance based design.

1. INTRODUCTION
In recent decades, the intense dynamic environment of capital markets have expanded to new regions of the world and have given rise to the new era of urban competitions among the current capital leaders and the new ones. Thus, the rapidly increased amount of tall building projects, in other words "the iconic-architecture of capitalist globalism" [1], became one of the strongest tools to brand the city by symbolically putting the national level of capital power forth. As a matter of fact, the global competitions of building "the tallest", "the most innovative" and "the greenest" and so on have generated impressive improvements in many relative fields.

While most innovations were mainly focused on the structural forms and energy production systems, unfortunately, the improvements in the safety design remained relatively out of focus. However, the overall innovative solutions have introduced many new materials and extreme conditions to the super-tall buildings which require reconsideration of the current safety issue based approaches. Therefore, this ongoing research aims to propose alternative solutions on management of making new technologies and innovations on the safety design of tall buildings.

2. INNOVATION AND PERFORMANCE BASED DESIGN
Every super-tall building project brings massive complexities within every phase of its overall project life-time. Considering the planning stages of the building safety against physical vulnerabilities, the main concerns could be grouped into 1) dynamic loads (e.g. earthquakes, wind), 2) fire and 3) extreme events (e.g. terrorist attacks) chapters. Considering the robustness of the system against fire, code based design approach is being dominantly used. Despite the unusual space orientations or irregular forms along the unusual height of super-tall buildings, the evaluation of the robustness of the overall system (such as design of egress...
system, real-time monitoring systems and the maintenance issues and so on) requires more than the building codes checklists. In the case of handling unique and complicated problems through the design of super tall buildings, the risk of miscalculations is naturally higher than any other ordinary project. Therefore, the building codes concerned should be integrated with performing realistic risk analysis, such as use of simulation software and performing actual tests and experiments (e.g. wind tunnel tests, dynamic force tests on new materials, etc.) [2]. Nevertheless, the fire safety design regulations in many countries still do not require either computer aided performance based design (PBD) analysis or actual tests for tall building projects. However, there are significant improvements achieved particularly on U.S. regulations after 9/11 terror for the enhancement of the safety of tall buildings.

Robert Solomon from National Fire Protection Association of the United States (NFPA) supports the previously mentioned approach and introduces NFPA’s newly developing tool which is called Leadership in Life Safety Design (LLSD) [2]. LLSD is a tool which is derived from Risk Indexing System and builds on the content of the CTBUH Building Safety Enhancement Guideline that was released in May of 2002.

LLSD is a model that can be considered by developers, owners and the design community to measure the impact of providing some redundant system, feature or enhancement to advance the level of safety. This tool is aimed to be used in parallel to LEED (The Leadership in Energy and Environmental Design) and BSC (Building Security Rating System).

Furthermore, LLSD considers the post-9/11 effects and recent innovative improvements in the construction industry and establishes following building parameters to that particular enhancement: Building configuration and general conditions, Building enclosure, Fire resistive construction, Elevator use and configuration, Stairs and enclosure, Areas of refuge / Special escape system, Building systems (e.g. independent power supply risers), Structural systems (e.g. testing the safety robustness of recent innovative structural systems), Security protocol (e.g. video camera, monitoring, e-ID check, etc.), Chem.-Bio Criteria (e.g. air quality sensors which are sensitive to any undefined organisms in the air), Operational Requirements (e.g. elevator criteria) and Innovational Special Design (e.g. testing new performance based design components).

After the 9/11 terror, most of the tall building possessors applied the eventually developed "Terrorism Risk Insurance" which includes the checklist of Federal Emergency Management Agency of the United States (FEMA). However, this checklist still requires recent updates such as at LLSD tool regarding the revision of new technologies and their relevant side-effects.

Reference [3] presents another example of fire protection strategy from Pearl River Tower, Guangzhou in China which was designed based on performance analysis and not fully addressed by China codes. Fire protection and life safety consulting specialist firm Rolf Jensen and Associates (RJA) was hired by Skidmore Owings and Merill, (the general contractor of the project) to achieve this target. RJA’s own "FireDynamicsSimulator" and
"PathFinder Egress Simulation" programs were used through analysis. It is also mentioned that China codes were often defective for the project. Hence, the code-plus performance analysis based design was highly necessary.

Another case, Burj Dubai which has not been completed yet though, already announced as the tallest building in the world, was engaged to numerous performance analysis based designs. Such as, the dynamic load of wind which was demonstrated by the specialist firm RWDI (wind engineering consulting services, sustainable design, environmental air quality, noise and risk services firm) as well as the structural robustness which was simulated by SOM (Skidmore, Owings & Merrill LLP) for the next 50 years predicted performance [4]. However, any structural health monitoring and real-time data recording/updating systems were not mentioned except for the simulation based structural design.

2.1. INTELLIGENT AUTOMATION SYSTEMS

On the other hand, the intelligent building automation and management systems have significant importance in increasing the physical robustness of the structure and the life-time of the building beyond increasing the property value in capital in the real estate market. There are several developments in this field such as wireless damage sensors [5] and real-time space and structural monitoring systems. PBD tools have again a significant role to generate realistic scenarios for building automation systems to be sufficiently structured to enhance the safety design. These improvements help to actualize faster evacuations as long as the type and the exact location of structural damages are able to be identified (e.g. the signals which flow along the steel structure reports any unusual deformations to the system center) and detect the resource of smoke/fires much faster than the conventional methods. So far, the innovation in the scope of intelligent building automation and management systems has a vital importance and this ongoing research focuses on the administrative models to procure the required business environment for improvements in this field.

2.2. COLLABORATION TECHNOLOGIES FOR INNOVATION

As it is observed through the above cases the PBD applications are one of the most important tools for the drivers of innovation in every field. In many cases the overall management of innovation process within construction industry requires integrated business architecture and knowledge flow [6]. In order to provide the requirements of producing new approaches, in other words "making innovation" the knowledge transfer among relative parties makes use of collaborative technologies that are shown in Figure 2 and Figure 3 [7], such as web-based
project hosting services, online project media for inter and intra firm communication (e.g. Buzzsaw, BuildOnline etc.). Some of these collaboration technologies include a system/media which record project-related discussions or pass messages between team members. Today, this rapidly growing online knowledge sharing system catalyzes better transfer of both implicit and importantly tacit knowledge which is generally hard to be materialized and transferred.

3. TALL BUILDING CASES FROM JAPAN

Not so long time ago, in 1968 the first tall building of Japan, Kasumigaseki Building was accomplished. This project was a big challenge for Japanese engineers and architects who were not experienced to solve the physical complexities of a building that is higher than 10 stories in Japan where the wind and seismic loads are relatively higher than any other places in the world. The structure design of the building was initialized by the concerns of seismic loads and the overall anti-seismic structural design was tested through the simulations of El Centro earthquake CA, 1940 model. Besides this, the H-shape steel columns were developed for the first time in the world and many other impressive construction innovations were achieved within the Kasumigaseki project. During this project, the scale of innovations covered several different industries and gave rise to an impressive interdisciplinary teamwork.

The implication of this project had a very unique way of knowledge management. The decision making mechanism was divided into two: gradual by roles which was company based and network type by divisions. "Vision-driven goal sharing" structure of the collaborations among the client, main contractor, subcontractors and consultants generated a highly qualified teamwork. For instance; the technical meetings were realized including every stakeholder in the same place around a hundred times. As a matter of fact, the main characteristic of the project was "the combination of tacit knowledge, experimental knowledge and collected materials" [8].

3.1. METHODOLOGY OF THE SURVEY

This research is being realized respectively in Japan, U.K. and Turkey. Japanese case survey of construction innovations in tall building projects had been initialized by learning from the history of "Kasumigaseki Building" and continued by conveying investigations on the recent examples such as in Figure 4 and Figure 6. The investigations were realized through structured interviews and followed by questionnaire surveys. The interview part of the research aims to obtain information about the knowledge transfer among main contractors and subcontractors/consultants in the process of improving a new system which enhances the physical robustness of the building. Interviewees were mainly fire engineers, structure engineers, façade engineers and project managers who had been involved in tall building projects before. Prior to forming the interviews’ outline, twelve important factors for the management of innovation were detected based on previous researches and observations. Subsequently, these twelve factors were grouped under the four main innovation triggering or hampering factors which are listed in Table 1. Therefore, each one of the interview questions refers either one or more of these subfactors. In Japan, the most advanced five Japanese construction companies which are called "general contractors" dominate over most of the tall building projects in Japan and also perform overseas. These companies maintain a very advanced level of in-house design, building and R&D activities. Therefore, general contractors in Japan are the system integrators in many cases of innovative construction works and generate a suitable environment for inter and intra firm knowledge to be managed integrally.
In the Japanese case of this research, interviews were made both with the general contractors and the subcontractors which had been involved with either "design & build" type tall building projects or the tall building projects where the design and construction works were achieved by independent stakeholders through modular business architecture.

For each interview, the questions were rearranged according to the interviewee’s and the company’s position during the mentioned project life-time. Only one of the investigated tall building projects was not completed in Japan but in Dubai. This project is still under construction and executes distinctive knowledge management rather than traditional Japanese applications. Along with this, the project brings Japanese design and engineering consultant companies together with numerous international parties in the project’s platform.

### TABLE 1

<table>
<thead>
<tr>
<th>Main Factors</th>
<th>Subfactors</th>
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<td>Slack Resources</td>
<td>- Contract Flexibility</td>
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<td></td>
<td>- Financial Flexibility</td>
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<td></td>
<td>- Alliance Tendency</td>
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<tr>
<td>Knowledge Mobility</td>
<td>- Scale of inter-firm knowledge transfer</td>
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<td></td>
<td>- Way of knowledge transfer / Effective information gathering capability</td>
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<td></td>
<td>- Broadness of task assignment</td>
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<td>Strength of Integrators</td>
<td>- Strength of internal integrators</td>
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<td></td>
<td>- Strength of external integrators</td>
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<tr>
<td></td>
<td>- Process Overlapping</td>
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<tr>
<td>Scalable Performance</td>
<td>- Continuous Improvement / R&amp;D</td>
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<td></td>
<td>- Building Codes</td>
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<td></td>
<td>- Performance based design usage</td>
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### 3.2. OBSERVATIONS

In the case of general contractors’ design and build model in tall building constructions, the observations show that the integrity of the project slightly increases the knowledge mobility among the general contractor and subcontractors. In western countries opposite to the Japanese integrated model the construction business architecture tends to be modular in most of the cases. Regarding the comparisons in between modular and integral system practices construction works are often likened with the automobile industry [9]. The horizontal technology transfers from Lean production to Lean construction approve the system similarities between these two industries.

**FIGURE 4**

HAYEK CENTER, GINZA-TOKYO
Below Figure 5 briefly shows the relation between knowledge mobility and business architecture through the cases of semiconductor industry, automobile, and LCD (Liquid crystal display) industries [10].

According to the survey observations in particular, the code-plus PBD activities in Japanese case of tall building projects is likely to be slightly more modular where the mobility of knowledge is higher than the automobile industry. This circle hypothetically shifts for different countries affected by cultural matters. Subsequently, the appropriate combination of explicit and tacit knowledge mobility would keep the circle at the optimum level if the required amount of improvement in the weaker part is known empirically.

![FIGURE 5](image)

**FIGURE 5**

**RELATIONSHIP BETWEEN KNOWLEDGE MOBILITY AND BUSINESS ARCHITECTURE**

Observations have also pointed out that the use of collaborative technologies in Japan is less than half of the cases. However, the frequency of the knowledge transfer is higher than in western countries. The transferred knowledge was concerned as explicit and tacit knowledge. According to the interviews, the explicit knowledge transfer in modular and integral business models are similar to each other. Besides this, the knowledge mobility of tacit knowledge is likely to be relatively higher in the integral business model where most of technological developments were performed 50% or more in-house. In the case of modular models where the construction works are performed by other than the design phase stakeholders, innovation is mostly developed during the design phase by the collaboration of the architect and the consultant engineers which is highly influenced by the demands of the client. However, in this model manufacturing, subcontractors are unlikely to have any knowledge transfer from the origin of the innovation makers. Because of this reason in the meantime, significant tacit knowledge which may inspire another innovation or be improved in the future just disappears.

Moreover, the observations show that the fire safety regulations in Japan neither require scenario modeling and fire safety risk assessment nor allow the use of CFD (Calculation Full Dynamics) and some advanced fire detectors for tall buildings. On account of the circumstances, in some cases solutions are likely to be restricted by regulations and designers may tend to use only code checklists.

On the other hand, in the case of overseas projects of Japanese stakeholders, several organizational fragmentations were observed. The main problems can be summarized as the inexperienced client, inexperienced project manager, no risk assessment, insufficient degree of explicit and implicit codes mobility, communication problems because of cultural and organizational incompatibilities, no flexible resources and dominance of traditional methods.
As a result, the qualitative ratings of the necessary innovation catalyzing factors that are listed in Table 1 were relatively low for this project.

4. CONCLUDING COMMENTS

According to the observations of the interview survey, Japanese qualified level of collaboration in construction projects are likely to be catalyzed by two domain factors:

1) Cultural matters: The tendency of teamwork in the Japanese construction industry is relatively higher than individualism and so is mutual reliance.

2) General contractors: High quota of general contractors in the Japanese tall buildings construction market allows them to perform a continual collaboration with their subcontractors, to specialize in horizontal technology transfer and create multidisciplinary knowledge as well as "technology fusion" [11].

Each super tall building is another challenge and one of the most significant accelerators of the construction innovation for the industry. Tall building projects rise opportunities to develop cross-industrial collaborations and improve the technology fusion approach in the industry.

Therefore, due to the above reasons the industry is highly in need of organizational rearrangements to improve advanced alternative solutions to enhance the vulnerable factors of increasing amount of tall buildings.

Consequently, the post-disaster effects such as structural and infrastructural damages in tall buildings occupy another significant discussion area on robustness of the overall system and the project. The terms "technology fusion", "business architecture models" and "code-plus performance analysis based design" is suggested to be more focused from the perspective of the management of

This research is planned to be improved through international case surveys in Japan, U.K. and Turkey in order to distinguish the differences in business architecture of construction innovations in different continents through different cultures. Finally, in order to reinforce the continuity of building operations against any kind of disasters, more case studies and deep investigations are needed.

REFERENCES


