# INTERNATIONAL STUDY ON FIRE PREVENTION TECHNOLOGY DEVELOPMENT AT ORGANIZATIONAL LEVELS

Hande ÜNLÜ*, Tomonari YASHIRO**
PhD Candidate, the University of Tokyo, Institute of Industrial Science*
Professor, the University of Tokyo, Institute of Industrial Science**

***ABSTRACT*****:** This is an ongoing research on management of technology development in fire prevention systems for high-rise buildings. Within this research fire prevention technologies are investigated through international cases in high-rise building projects from Japan, UK, Germany and Turkey. Each one of these countries showed very distinctive mindsets on "Resources, Process, Priorities" (RPP theory). Such as British cases showed advanced setups for management of knowledge since early stages of projects while in Japan process gains the strength from integrative approaches which is way far from Turkish cases. Moreover, German cases showed the highest reliance on conventional systems in fire prevention technology which is relatively different than the technological improvements in other industries in Germany. Qualitative comparative analyses were realized based on best practice models and interview observations in the mainframe of risk management approaches.

***KEYWORDS***: fire prevention systems, management of technology

## 1. INTRODUCTION

Every year in the world more than thousands of people loose their lives due to fire events. Still in the 21st century fire is one of the most fatal disasters. Only in US every year more than 4000 people die in fires and direct property loss due to fires is estimated at $8.6 billion annually (Federal Emergency Management Agency in US). More sadly, all over the world these numbers are increasing every year despite the efforts in fire prevention and protection strategies.

Basically, there are two types of fire protection systems concerned in the field that are passive and active protection systems. Table1 shows today's the most frequently focused global research and development areas in fire protection systems. Macro level and external systems are very hard to be changed and improved although globally, there is a significant need in this level (Oven, V.A. and Cakici, A., 2008, Guo, T.N. and Fu, Z.M., 2007, Tavares, M.R., 2009, CTBUH Fire & Safety Group Brief, 2009). There are respectful international and global size associations, organizations and institutions such as International Code Council (ICC), Society of Fire Protection Engineers (SFPE), Council on Tall Buildings and Urban Habitat (CTBUH) Fire&Safety Work Group, European Committee for Standardization (CEN) and many more actively working on detecting the differences, proper needs and long-term rehabilitation strategies at both developing and developed countries. But still some vitally important factors such as nationwide fire safety awareness and the education in developing countries are not adequate and need long-term well structured improvements. Under such circumstances, a benefitial utilization of most of the micro level fire protection systems (See Table1) and the latest technologies become impossible. As Tavares, M.R., 2009 discusses that the requirement of qualified engineers with proper knowledge of Computational Fluid Dynamics (CFD) in practice is a very basic need but a big problem in many developing countries. This is a problem of not adequate intellectual infrastructure in macro level

On the other hand, development of micro level and internal fire protection systems (See Table1) are likely to be developed on more flexibly configurable factors but surely, take time and require series of procedures (e.g. technical approvals, authority inspections, etc.) to be put in effective use.

## 2. OBJECTIVES

This paper explores the significant organizational and regulative obstacles in development of fire protection systems/technologies in different countries. Besides, hypothetically discusses the merits and possibility of quantifying the essentials of international technology transfers, limited to the case subjects. Section 3 introduces recently emerging fire prevention technologies and the organizational tools to transfer and utilize these improvements internationally that are empirically limited with the case subjects. Section 4 argues the methodology of case surveys and the need in focusing on high rise building fire safety cases. Section 5 presents the survey outcomes and introduces the next survey's statistical analysis steps. Section 6 discusses these outcomes as well as introducing the future works.

## 3. FIRE PREVENTION TECHNOLOGIES

During fire events, expose to heat and smoke can become more dangerous than fire itself due to poisonous gases. Asphyxiation[1] is the leading cause of fire deaths, exceeding burns by a three-to-one ratio. Besides, collapse and explosion of building materials (e.g. glass) increase the risk of injuries as well as makes evacuation difficult for tenants. Regarding all these matters design of a building's overall fire prevention system (e.g. egress path, smoke barriers and compartmentation, alarms, structural fire proofing, suppression and detection systems) starts from the very beginning stage of the project. Adequate awareness of the above threats leads architects and engineers to implement a performance based design rather than purely relying on regulations (Solomon, R., 2008). Thus, it creates the first line of response (Cowlard, A., Wolfram, J., Empis, C.A., Rein, G. and Torero, J.L., 2008).

Today's main focus of research activities and technological developments in fire protection can be listed as in Table1.

Table1 Most focused developing areas in fire protection and their level and resouce identification

| | **LEVEL of Activity** | | **Resource of EFFECT** | |
|---|---|---|---|---|
| Activity Code | Micro | Macro | Internal (in-house) | External |
| P1 | | ● | | ● |
| P2 | ● | ● | ● | ● |
| P3 | ● | | ● | ● |
| P4 | ● | | | ● |
| P5 | ● | | ● | ● |
| P6 | ● | | ● | |
| A1 | ● | | | ● |
| A2 | ● | | | ● |
| A3 | ● | | | ● |
| A4 | ● | | | ● |
| A5 | ● | | | ● |

**P:** Passive fire safety system
**A:** Active fire safety system
**P1:** Regulations and Standards: Basically grouped

into two: 1) Performance Based Codes Adaptation Period in developed countries such as Improvements in Eurocodes, National Fire Protection Association of US, Building Research Institute performance based design motivations in Japan etc. 2) Improvements in Prescriptive Approach in developing countries.

**P2:** Qualifying Fire Engineers: Education about the recently emerging significant technologies in fire engineering and use of essential tools is both macro (nationwide) and micro (in-house) level effort. (Tavares, R.M., 2009)

**P3:** Evacuation Behaviour Research for better egress path design: Computer based simulations on human behavior is a significantly developing field. Multi-disciplinary collaborative platforms (institution-company-university) are in the focus of production.

**P4:** Material Science and behavior of new materials: Multi-disciplinarily developing long-term based research subject.

**P5:** Fire Statistics/Incidents Database: It gives a lot of cause-effect feedbacks from previous cases.

**P6:** Risk Assessment Strategies: Assessing the accebtable cost of necessary fire protection to avoid over-design is a significantly important concept during design. In fact, practitioners are still misled in risk assessment by using fire safety regulations as the criteria instead performance based requirements. On the other hand, performance based requirements have very independent parameters from project to project, there is no certain outline about what to be concerned how and until what level.

**A1:** Wireless Building Automation Systems: Highly promising and rapidly emerging technology in fire detection and information systems. However, there are still significant points which require improvements such as path loss, power life and security problems in actual use (Oksaa, P., Soini, M., Sydänheimoa L. and Kivikoskia M., 2008)

**A2:** Smoke Prevention Technology: It has been one of the most significant R&D concerns in fire safety field. Advanced smoke suppression technologies in particular from Japan, is integrating to other response technologies to set a robust network of protection.

**A3:** Chemical Gas Components: Recent works such as on Hypoxic air (oxygen reduced air as in flight cabins) during fire is claimed to help tenants make safer evacuation and avoid Asphyxiation symptoms.

**A4:** Fire Robots: Fire departments in UK, Japan, US, China and many other countries are working on developing fire fighter robots (Guo, T.N. and Fu, Z.M., 2007). Concerning the breathtaking improvements in the robotics technology, humanoid fire fighting robots are becoming a more popular concern with such a motivation of life saving.

**A5:** Intelligent Detection Systems: For instance, IC tag type sensors are gaing more significance in construction industry. Via these sensors real-time, small size data transfer about several different features during fire events become possible (e.g. RFID technology (Swedberg C., 2006 and Lynch J.P., Kenneth J., 2006)).

### 3.1 International Technology Transfer and Joint Ventures

In addition to the contents of Table1 learning from previous cases is another frequently utilized tool to make initial assessments on appropriate fire protection design (Gann and Salter, 2000). However, either referencing previous experiences or developing a new strategy each project has its very own independent parameters. As it is listed in Table1 some of the activities are in macro level and resourced externally such as national or international regulations and politics which cannot be controlled from project to project. But, countries do learn from each other's policies and best experiences so do the construction companies and other organizations. Therefore, understanding internal (in-house resourced) and external circumstances and identifying the characteristics of technical needs in a technology development process require robust organizational arrengements.

Concerning development of a fire prevention technology first, the critical issues of technology management must be analysed. Today, cross-industrial and international joint ventures are reasonably increasing in technology development process. But before starting up such a partnership, organizational capabilities must be well introduced by the each party in the mainframe of "Resources, Process and Priorities" (RPP theory of Christensen and Kaufman, 2000). As the RPP theory of Christensen and Kaufman discuss very often the cause of an innovation's failure is that the wrong processes were used in managing its development and execution (Henderson and Kim, 1991). Besides, unmatching and unclear priorities also particularly hamper international joint ventures. Some of essential features of "Resources, Process and Priorities" can be listed as below:

- Ownership and control: Corporate governance model of each party reflects both the organizational and the national business culture. Such as two-tier board system in Germanic and Japanese models tends to be more successful in incremental innovations (Miozzo, M., Dewick, P., 2002). (Innovation requires sustained effort. Slaughter, E.S., 2000 describes incremental innovations being more frequent than radical innovations in construction industry.)
- Management structure: Construction innovations aren't implemented within the firm itself but as part of projects in which firms are engaged. Both regionally and functionally decentralized organizations tend to adapt better in international joint ventures and generally present more stable improvements.
- Intellectual Infrastructure: Includes regulations, technical capabilities of engineers and social awareness of fire culture. Cultural and technical miscommunication may become the main barriers during international collaborations.

This paper highlights the above listed issues which are naturally nourished by several other sub-factors. However, here we point out only the most significant organizational level factors related to and through the case subjects.

## 4. METHODOLOGY

### 4.1 Fact of Today's High-Rise Buildings

Since the beginning of the world's civil history structural icons (particularly tall ones) were widely used to label cities, lands and wherever the commanding power of time had emerged. As a matter of fact in our time, rapid increase in the height range of the latest "iconic buildings" has brought highly complex demands into the field. In terms of fire safety designs neither the regulations nor the conventional approaches meet enough the need of actual cases anymore. Therefore, performance based solutions and evaluation of potentials from a multi-disciplinary perspective are strictly required. However, explicit and tacit knowledge to evaluate or measure the setup of required actions in management level are highly fragmanted and fragmantedly carried out by different players. Series of confusing standards, qualified engineer requiring complex performance based design softwares and other high demanding features in complicated projects basically, have been faciliated independent from each other.

In such process flow, due to the need of fact, integration catalyzing tools/systems in every dimension have vital importance. As Rebentisch and Ferretti 1995 state that "technology is no other than an embodied knowledge". Therefore, during this embodiment process management of knowledge cannot be thought apart from management of technology development.

### 4.2 Case Surveys

Significant technological improvements cannot be achieved without collaborations (Christensen, M.C. and Kaufman S.P., 2000). Today, most of the innovations are realized cross organizational and national boundaries. Based on the need in improving organizational capabilities for such international joint ventures within this research, international case surveys in high-rise building projects are being realized in Japan, UK, Germany and Turkey. Each one of these countries presents very distinctive fire and building regulations, resources, process and priorities (RPP theory).

Surveys are grouped into two sequential steps as interview and questionnaire surveys. The aim of the interview survey was to identify the critical activities during technical challenges and in particular fire safety design in high-rise building projects. The aim of the questionnaire survey is to classify the essential activities and to quantify the interdependencies in between. Hypothetical equations will be limited with fire safety design in high-rise building projects from four different countries. However, the logic could be configured and applied to the management levels in other technological developments as well.

## 5. SURVEYS

### 5.1 Observations from the Interview Surveys

Between the period of 2008 December to 2009 June, 42 interviews were realized with "Fire, Structure, Façade, Electrical and Mechanical Engineers as well as Project Managers and local authorities" in each case country. Interviews covered 16 tall building cases (which are taller than 60 meters), 6 construction innovation cases and 7 different management specialties.

#### 5.1.1 Japan

Interviews at Japanese construction and consultant companies showed that the strength in technology development during high-rise building projects basically stands on the unified organizational and intellectual structure. There is a frequent collaboration and know-how transfer between construction companies' Research and Development (R&D) centers and institutions (universities, Building Research Center, etc.) in Japan. Organizational capabilities in terms of size, ways in transferring knowledge, decentralized management structure and ownership/control models of both general (main) contractors (called *ZeneCon*, Reeves, K.,2003) and suppliers are often very similar. Therefore, Christensen and Kaufman's essentials of "Resource, Process and Priorities (RPP)" theory for incremental innovation in construction technologies are met by the collaborating parties.

As it is shown in Figure1 in Japanese projects usually, architect is the system integrator during design phase and general contractor is the system integrator during the construction phase. In Japan knowledge management is based on quality management regulations, face to face meetings and drawings and e-mail exchanges. Intranets are mostly used for project database, discussion portals are relatively simple. On the other hand, in Japan shifting to performance based codes from conventional codes had showed a smoother period than in US. It is again likely to be an outcome of unified broad knowledge level of practitioners and also an outcome of strong central regulative system

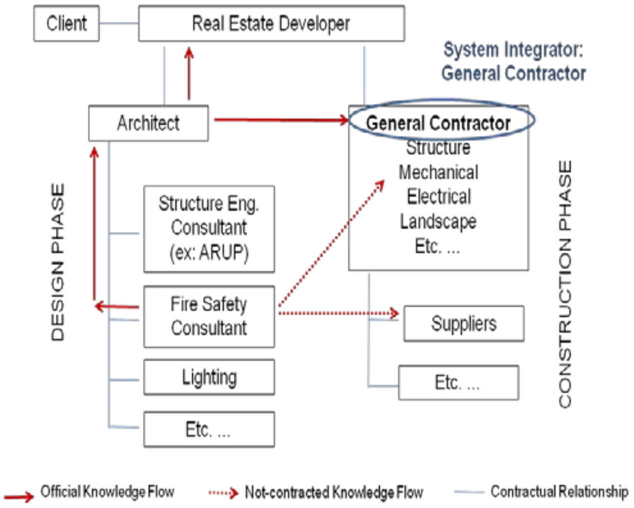


Figure1 Japan case: Most common project implementation model in high-rise building projects

unlike in US or China. In US the system of regulations that change from state to state make shift to performance based codes period difficult.

### 5.1.2 UK

In UK it is observed that main contractors who are the system integrators are usually professional project management firms. UK projects are quite fragmented in terms of roles and functional process (See Figure2).

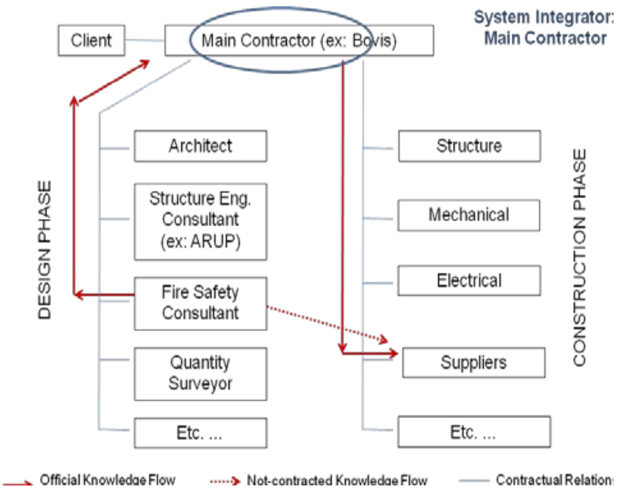


Figure2 U.K. case: Most common project implementation model in high-rise building projects

Not long but a decade ago largest construction companies of UK decided to shift their investments from R&D to project management abilities. They decided to outsource R&D activities not only within UK but also from overseas. Due to the fact, large British construction, management and consultant companies have strongly decentralized structure both regionally and functionally. As a matter of fact and actual need, British construction companies developed very advanced management tools for knowledge share, transfer and store both in-house and cross-partners (with institutions, authorities, suppliers, etc.).

Another interesting and an important point for technology transfer at British construction companies is the corporate governance model. Most of the British construction companies are controlled by Anglo-Saxon[2] model which is similar to the models in US but different than in Germany, Japan and Turkey. This system is more self-regulative and it depends on more company principals rather than rules. Thus, within British innovation initiations there is more room of freedom during international technology development and ventures. So, the "Priorities" of the firm must be well identified due to being the foundation of management model of a company. Because of these reasons, this model is likely to be appropriate for radical innovations rather than incremental ones.

### 5.1.3 Germany

In Germany case we observed some similarities to Japan case in terms of organizational integrity of general contractors and likely to be less fragmented than in U.K. or Turkey cases (See Figure3).

German general contractors have capability of in-house R&D and strong cross-industrial technology development. General contractors in certain size must be controlled by Germanic two-tier board system[3]. Therefore, long-term relations with partners and incremental innovations are more possible.

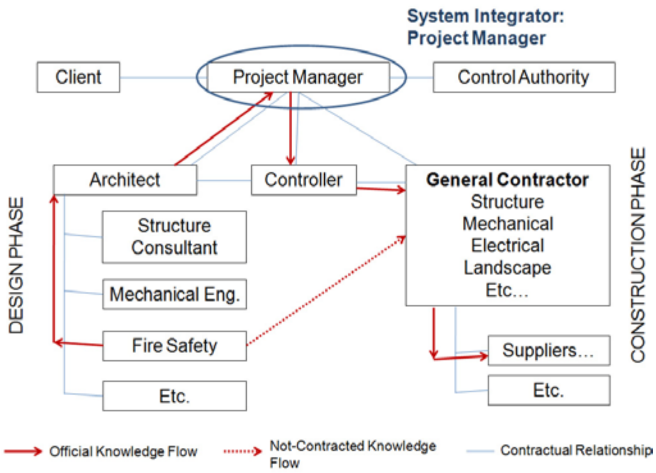


Figure3. Germany case: Most common project implementation model in high-rise building projects

On the other hand, in Germany government regulations, government initiatives and its institutions are relatively dominant in every field. Not much freedom is left for radical innovations. However, government's institutions are one of the largest and most advanced in Europe such as DIBT (Deutsches Institut für Bautechnik) therefore, all technological improvements are controlled by government. As a matter of fact, rule based organizational structures are more likely to develop technologies in a long-term sustained ways.

In regard to the fire prevention systems German regulations still strongly depend on conventional techniques. Macro level and passive protection systems are more relied in Germany rather than emerging technologies mostly on active protection systems (See Table1).

**5.1.4 Turkey**

In contrast to Germany, Turkish construction industry is likely to be open to the emerging technologies. However, during the interviews it is observed that in most of Turkish construction companies "Priorities" are set on acceptable gross margin. This situation often hampers the investments in technology development or transfer in construction industry. Turkish construction projects in case of high-rise buildings showed the most fragmented architecture among the survey countries. As it is shown in Figure4 main contractors are the system integrators during the construction phase and during design phase architect is likely to be the integrator.

Turkish main contractors outsource R&D activities from government institutions and universities. Another interesting point is that almost every advanced technology including fire prevention systems in high-rise projects in Turkey is an imported technology from abroad, mostly from Germany.

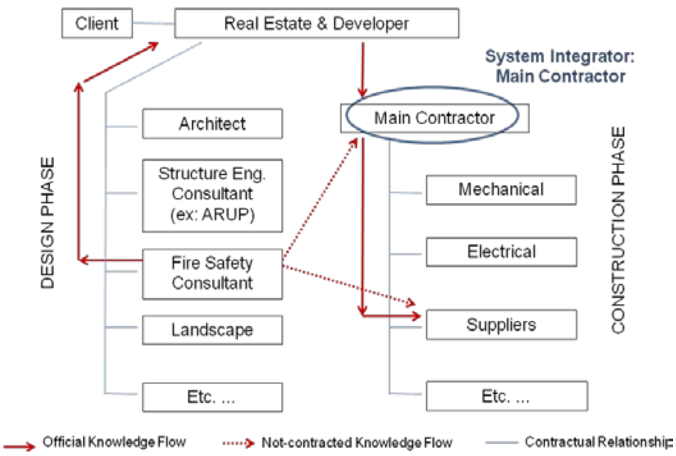


Figure4 Turkey case: Most common project implementation model in tall building projects

Interviewees outlined that the enacted Turkish Fire codes in 2002 was a good motivation for the sector on the way the nation preparing to enter European Union. However, these rules which need performance based complex evaluations, are still not well understood by Turkish practitioners. As it is seen in other developing countries such as China and Brazil, initial to performance based codes, first, Turkey needs to improve the intellectual infrastructure. Education of fire culture and technical skills to utilize performance based design tools must be the priorities in Turkey.

### 5.2 Questionnaire

Considering the obtained observations from the interview survey, a questionnaire survey is realized in order to test and hopefully, to prove the hypothesis through empirical configurations. Thus, expected configurations have the merit and the originality of defining characteristics of knowledge flow in Japan, U.K., Germany and Turkey during development of construction technologies particularly in high-rise building projects.

Therefore, the expected explicit outcome of this research aims to establish a tool for organizations to evaluate the robustness of their management strategy of developing a technology in complex projects. If a company knew its own and its partners' characteristics of capabilities in explicit terms (including the magnitudes of interdependencies and independencies), it would be easier to configure the resources, process and project priorities in early stages for their joint venture.

#### 5.2.1 Structure of the Questionnaire

Questionnaire is planned to be realized with same and more companies from the interview survey. During the design of the questionanaire first, the main features of technology management, fire prevention systems and challenging high-rise projects were identified through the interviews. These features were then grouped into project phases according to their occurrence time. Anwers will be given over 0 to 5 rating method twice for each question. First answer will be about the asked features' actual effect on the metioned high-rise building project. 0 represents no existence of the feature, 1 represents less than 20% of cost increase, schedule shift, serious quality loss. 2 is for 10-20% and 3 is for 5-10% cost increase, schedule shift, unacceptable quality loss. 4 is for less than 5% cost increase, schedule shift, affected very demanding applications only. 5 is for insignificant cost increase, schedule shift, quality loss. Second answer will be about the same features' general importance along technology development process within the respondent's company. Survey is recently being realized and planned to be completed by April, 2010.

## 6. DISCUSSION

Observations from the surveys showed different obstacles and motivations that are dominant through the lifetime of technology development in each country. Basic characteristics of each country's essentials from the "Resource, Process and Priority (RPP)" theory are illustrated through Figure 5, 6, 7 and 8.

In Figure5 and 7 it can be seen that the priority platform bears similar factors in Japan and Germany. This may explain the size and frequency of Japanese direct investment in technology in Germany of being one of the largest in Europe. On the other hand, Process characteristics show more distinctions that are mainly based on Germany's high reliance on Conventional Outlines in fire safety design. This also could be explained by not adequate motivation in the field of high-rise buildings. In Japan we observed the dominance of Inter-disciplinary Integrated System Architecture Approach in technology development on formation of the process.

In British construction companies, the Project Management System architecture synchronizes the fragmented job packages to the entire project. As in Figure6, Project Management and Outsourcing are the most dominant principals that form the process frame around the resources.

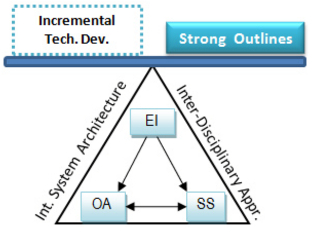


Figure5 RPP model in Japan

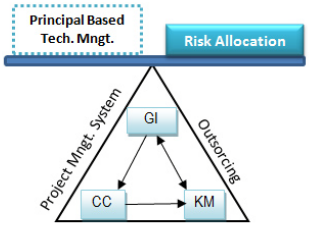


Figure6 RPP model in UK

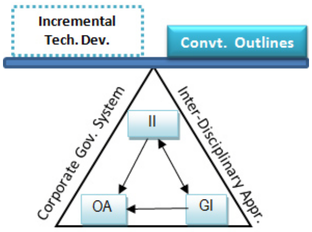


Figure7 RPP model in Germany

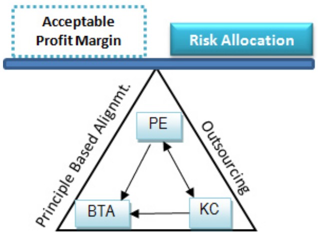


Figure8 RPP model in in Turkey

EI: Educational Infrastructure
OA: Operational Abilities
SS: Size of Suppliers
GI: Government Initiation
CC: Concious Client
KM: Knowledge Management
II: Institutional Infrastructure
OA: Operational Abilities
PE: Policy Establishment
BTA: Broad Task Assignment
KC: Knowledge Capacity
→ Resource feeding direction
△ Process frame    Priority pltform
Project-based flexibility

On the other hand, due to the dominance of outsourcing in fire prevention technologies, there is a worry about the maintance of technology. Same cause-effect situation is also observed in Turkey too. Besides, in Turkey most of the project engineers have same average Knowledge Capacity about fire safety design and tools. Average level of knowledge in many different aspects is very common in Turkish construction companies. Therefore, Broad Task Assignment is one of the most the dominant resource and strength. However, in technology development expertness is required in higher levels.

It is observed that during particularly in fire prevention technology, company and project based priorities stand on the micro level resources. Flexibility in aligning process and resources to task has a significant importance of sustaining the priorities. Therefore, each case can learn from each other's strength and weakness in structuring the RPP balance and evaluate the degree of essential arrangements on its own priority platform.

### 6.1 Future Works

This paper presented different approaches in developing fire prevention technologies and its importance in high-rise building projects. In order to test the validity of the statement under distinctive circumstances and culltures more international technology transfer and joint venture projects must be studied.

### APPENDIX

[1] *Asphyxiation* is a fatal condition resulting from inhalation of carbon monoxide, frequently occurring in association with inhalation of smoke exhaust. The failure or disturbance of the respiratory process brought about by the lack or insufficiency of oxygen in the brain. (Encyclopædia Britannica)

[2] *Anglo-Saxon* corporate governance model is a single-tier board system where executive and non-executive directors sit together.
*Germanic* corporate governance is a two-tier system also known as Continental European model where a Supervisory Board consists solely of non-executives and a lower level management board consists of full-time managing directors. Supervisory Board totally independent from management board (International Chamber of Commerce definitions).

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