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Factors Affecting the Transition from Prescriptive to Performance- Fire Codes in Korea, Poland and Brazil

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Abstract

Economic growth, increased urbanization and construction volume can place pressure on building regulatory systems and influence building fire safety. The more rapid or widespread the changes, the larger the pressures can be. One solution is to move to performance-based approaches. This requires appropriate regulatory, education and research infrastructure. Criteria for successful transition to performance-based approach to fire safety are suggested. Using the criteria, three countries moving toward performance are evaluated, and a roadmap for successful transition to performance is suggested.

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Authorship

Jin Kyung Kim was responsible for writing all information relating to Korea, the introduction, scoring rubric for urban environment settings, the conclusion and all information in Appendix A.

Andrew Canniff was responsible for writing all information relating to Poland, the abstract, rubric for education, and all information in Appendix B.

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Executive Summary

Prescriptive building codes have long served as the primary instrument influencing the level of safety in buildings. These codes have typically been developed over decades and often encompass several hundred pages of detailed requirements. While such codes work well for 'typical' building design, they can be unwieldy for innovative designs, and the regulatory infrastructure can be poorly equipped to address alternative designs. This can be problematic when rapid changes occur in the construction sector, including development of more and taller buildings and unique structures: factors associated with rapid urbanization, densification, and the desire to have 'world class' buildings.

To facilitate a better regulatory response to the changing needs of the construction sector, and to address the pressures of urbanization and densification, many industrialized countries have recognized the need for regulation reform. In particular, a transition from prescriptive-based to performance-based regulations and design approaches. The argument is that such reforms can result in an increase in the flexibility of building design options, greater innovation, and higher levels of safety in buildings, all with lower costs and a decrease of the regulatory burden.

However, such a performance-based system needs an underlying infrastructure of its own. This includes the need for a strong number of trained individuals who will competently judge the safety factor of a building, an education that includes the fundamentals of fire protection engineering in a curriculum that will supply the demand for fire experts and a regulatory structure that is capable of effectively enforcing the fire codes.

This project identifies some potential factors which might drive a country to consider a transition to performance, suggests some critical infrastructure factors which should be in place to support the transition, and analyzes the situation in Korea, Poland and Brazil with respect to building fire safety performance. A comparative analysis is performed on these factors to distinguish the areas that the respective country is greatly contributing to the performance-based codes and to highlight the deficient areas. Lastly, as a result of this analysis, a road map is generated to serve as a guideline for countries that will transition to performance-based codes in the future.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

The world regards unwanted fire as a risk to life and property. Increased understanding of fire characteristics and behavior over the centuries has led to improved fire protection systems, suppression methods and stringent building codes. Tireless efforts to improve fire safety have resulted in advancements in technology for assessing and design fire safety for buildings. These advancements have also helped facilitate a transition to performance-based (PB) building codes and design methods, which began in the 1980s and 1990s. (Meacham, Bowen, & Traw, 2005)

The traditional prescriptive based building codes, such as introduced in the early 20th century in the USA, generally provide fire safety with a combination of prescriptions according to the hazards presented by common occupancy groups. These codes are typically based on judgment and experience rather than on science and engineering. By contrast, performance-based building codes require scientific knowledge and engineering principles. The performance-based approach requires identifying hazards and risks to establish safety goals and appropriate design scenarios for specific applications. The design scenarios need to be evaluated for verification which may be done by implementing computer models or running experiments. This approach of considering hazard identification, scenario development, and evaluation of buildings against the scenarios of concern is called performance-based design (PBD). (Meacham, 1998).

Having been established over a long period of time, the prescriptive codes have proven to work and are straightforward for designers to implement and for officials to enforce. However, the prescriptive codes generally lack details of the effect of the requirements, how much safety is provided and quantification of the safety factors. As a result, prescriptive design approaches could result in redundancies to increase overall building costs especially in large-scale complex buildings. Because performance-based design within a performance-based building regulatory system can be cost effective and provides greater flexibility while achieving the required minimum fire safety levels, the current international trend has seen a growing interest in undertaking performance-based approaches for building fire safety design. A host of countries such as Australia, Japan, New Zealand, Scotland, Spain and United Kingdom, have already successfully transitioned to a performance-based system. (Meacham, Bowen, & Traw, 2005).

However, it is not only the architectural style or size of a building which influences the transition towards performance-based codes. There is often also some driver in the economy, such as increased urbanization, densification or other growth in the construction sector. A strong economy is required to support the construction sector with the required technology and skills in order for high-rise or complex structures to be introduced to cities (e.g., see Building Regulation Review Task Force, Final Report, *Microeconomic Reform of Building Regulation*, 1991). Typically, urbanization has a domino effect and induces growth in multiple areas, which could often time set up an environment where performance-based codes could become a necessity. Population density increases as a result of the influx of rural population migrating into cities. To accommodate for the exponential growth and limited land area, new construction of high-rise buildings occur. The construction sector grows and becomes a big contributor to the nation's total gross domestic product (GDP). As the construction sector and economy grows, new technology is introduced to support and encourage taller, bigger and ever more complex buildings, setting the tone for need of implementing performance-based codes to greater effect and appreciation. Even if the settings for implementation of performance-based codes are well established, without properly educated fire protection engineers, performance-based approach cannot be implemented. A well-established fire protection engineering education program is essential to produce the required fire protection engineers to undertake performance-based design: engineers with profound knowledge of fire behavior and characteristics, fire impacts on people, and fire mitigation design strategies.

A study of the current state of building and fire codes of Korea, Poland and Brazil, all countries with predominantly prescriptive codes that are currently on course or looking to transition to performance-based codes, was conducted to gain familiarity with each country's building and fire code environment, with a focus on fire safety aspects. Also, urbanization and education were identified as potential drivers of performance-based fire codes and closely examined for each of the country. A scoring rubric was established for each driving factor by breaking down the broad factor into smaller components related to the bigger picture of the factor in general. All of the countries were given a score based on the information garnered, for all of the subcategories established in the scoring rubrics to quantify and see what areas needed improvement to successfully transition to performance-based fire codes. From this study, a road map for transitioning to performance-based fire codes was created. The road map identifies the steps and the required components to move forward and establish a successful performance-based approach.

Chapter 2: Background

2.1 Introduction

There is not one particular trend which motivates a country to transition to performance-based codes (Meacham, 1988). Instead it is a multi-dimensional movement. The three general areas driving a national transition to a performance-based code system for this report have been identified as Urbanization, Fire Code Policies, and Fire Protection Education and Market Capacity. In this chapter the current atmosphere of Urbanization, Fire Code Policies, and Fire Protection Education of Korea, Poland, and Brazil will be outlined. Specific areas of focus within urbanization for this chapter are Urban Setting, Economy, Infrastructure, and the Construction Sector. All four dimensions of urbanization under investigation contribute to the general push towards performance-based codes. The second general driving factor, Building and Fire Code Policies, is separated into three subdivisions: Uniformity of Codes, Code Development, and Implementation of Codes. Finally, the third driving factor, Education and Market Capacity, has three areas of investigation: Fire Protection Programs, Current Situation of Fire Protection Engineers, and Market and Regulatory Needs for Fire Protection Education. The information in this chapter will provide contextual information pertaining to each of the three "developing" countries for the three driving factors and will assist the comprehension of our subsequent comparative analysis in the following chapters.

For the purpose of this study, urbanization is defined as the movement of persons within a country from rural settings into urban environments. This may be a result of job opportunities, immigration policy or other factors. Outcomes of urbanization which are of concern to this study include increasing population, increasing population density, and resulting impact on the built environment, including high-rise buildings, slums, infrastructure issues and the like: factors which place stresses on the building regulatory system and on fire safety. As noted above, we address these for each country in terms of Urban Setting, Economy, Infrastructure, and the Construction Sector.

The next factor taken to account is the approach each of the three countries takes forming fire codes. This is defined as the set of documents that dictate the standards for a building to be deemed safe and varies from country to country due to different government systems. The factors that are concerned with the transition to performance base codes include factors such as the code uniformity, the methods in which codes are developed and the level at which these codes are enforced. It is important to note that these factors have little relevance with the economic situation of the country.

The last factor, education and market competence, was defined as the capacity to educate and produce fire protection engineers and the available opportunities for these fire protection engineers in the current domestic market. Outcomes of education and market competence which are of concern to this study include available fire protection engineering programs being offered, research being conducted to complement the transition to PB fire codes, current experience of fire protection engineers to perform PBDs, the market demand for fire protection engineers seeking job opportunities and the regulatory need for fire protection engineers. All issues have an effect in the required knowledge and availability of fire protection engineers to actually carry out the PBD.

2.2 Korea

2.2.1 Urbanization

2.2.1.1 Urban Settings

By 2009 statistics, Korea's population has reached 49.8 million and 81.7% of the total population is considered urban population.

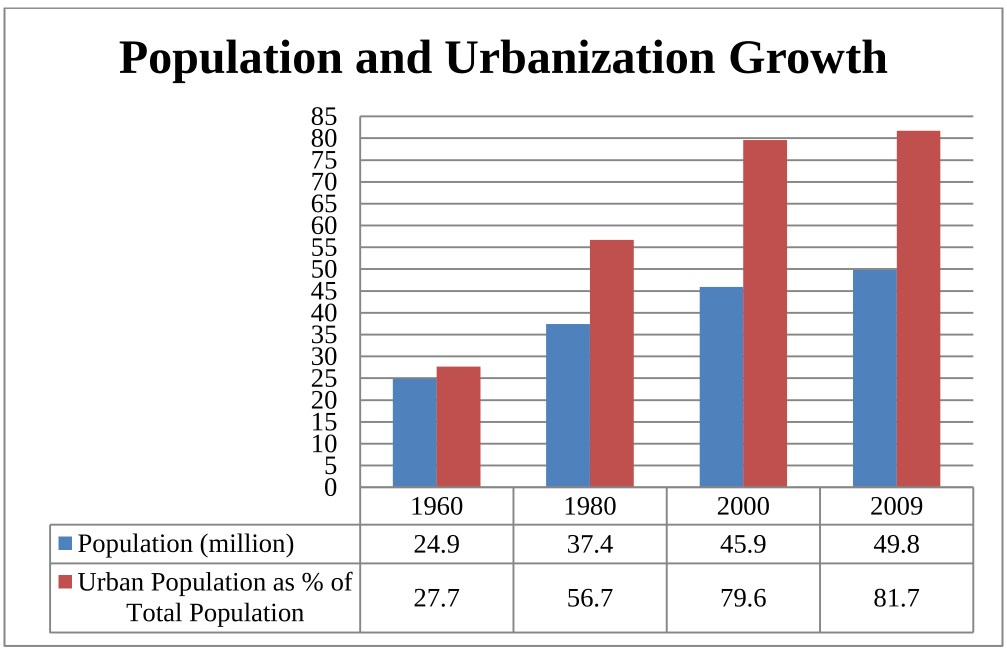


Figure 1: Population and Urbanization Growth of Korea (Global Finance, 2011)

Korea has become the third most densely populated country in the world with a population density of 476 people per km^2. Korea has a land area of 100,032 kilometers squared (slightly larger than the state of Indiana in the United States), and three quarters of the land are mountainous or water body areas. Korea is divided into 9 provinces. The figure identifies each of the provinces and the major cities within each of the provinces. (Jeon, 2007).

Figure 2: Map of Korean Provinces (My Life in Dongtan, South Korea, 2010)

Table 1: Population of Korea by each province (South Korea: Administrative Division, 2010)

Province	Total Population		
	2000 Census	2005 Census	2010 Census
Gyeonggi-Do	8,984,134	10,415,399	11,379,459
Gyeongsangnam-Do	2,978,502	3,056,356	3,160,154
Geongsangbuk-Do	**2,724,931**	**2,607,641**	**2,600,032**
Chungcheongnam-Do	1,845,321	1,889,495	2,028,002
Jeollabuk-Do	**1,890,669**	**1,784,013**	**1,777,220**
Jeollanam-Do	**1,996,456**	**1,819,819**	**1,741,499**
Chungcheongbuk-Do	1,466,567	1,460,453	1,512,157
Gangwon-Do	**1,487,011**	**1,464,559**	**1,471,513**
Jeju-Do	513,260	531,887	531,905
TOTAL	*23,886,851*	*25,029,622*	*26,201,941*

**Provinces in bold indicate a decrease in population*

It is clear from Table 1 that Gyeonggi-Do province, which consists of the capital city and other metropolitan cities, has seen the greatest population growth over the 5-year span. Several provinces have seen a population drop over the same 5-year period, with mass migration to the bigger metropolitan cities attributing to the cause. Today, with the majority of the economic activity being conducted in the Gyeonggi-Do province, the younger generations have a tendency to move to Gyeonggi-Do province seeking for better job opportunities.

Due to the scarcity of land and to accommodate for the growing population, Korea has seen the old traditional Korean buildings being replaced by high-rise buildings with vertical growth the answer to solve for the land shortage. With Korea's tumultuous history, construction and destruction have been an ongoing process. Hanok's have become obsolete as Western architecture having been introduced to the country as early as the 19th Century. Traditional Korean architecture went through greater transformation to the modern Japanese-style architecture during the annexation period under Japanese intervention, which was mostly destroyed during the Korean War and post-Korean War due to anti-Japanese sentiment.

Economic growth during the post-war period brought a wave of modern architectural trends and styles to the country. (Modern Period in Korean Architecture, 2010). Advancements and innovations in construction technology have led to an exponential growth in high rise buildings and complex buildings. The number of high rise buildings is shown in the table below. (Moon & Yoo, 2007). The data shows more than 96% of high rise buildings are residential apartment buildings, which can be attributed to the influx of the growing urban population.

Table 2: Number of high-rise buildings in Korea

Classification	Total	16 to 20 stories	21 to 25 stories	26 to 30 stories	31 stories or above
General Building	1,203	745	244	91	123
Apartment	29,501	18,004	10,263	1,091	143
Total	30,704	18,749	10,507	1,182	266

**Data from Korean National Emergency Management Agency (2008)*

Figure 3 delineates the mountainous topographical characteristics of Korea as well as the urban sprawl in metropolitan cities.

Figure 3: Sky view of Seoul, Korea (Seoul Becomes Urban Green Leader, 2010)

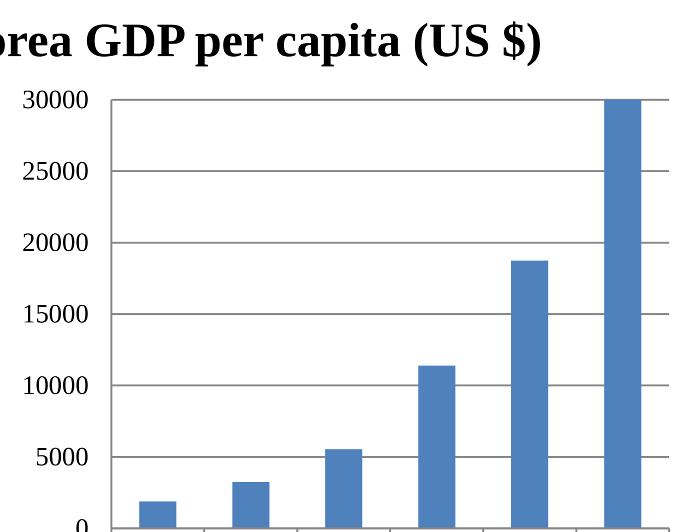
Due to the increase in both high-rise buildings and population density, the urban settings have been a great cause of concern in terms of fire safety. There are areas in the cities where the road is too narrow and buildings are built so close to one another that fire trucks have a hard time accessing some of the buildings. Also in high-rise buildings, there are concerns over spread of toxic gases through elevators, shafts or other vertical passages which can trouble occupants from evacuating. The 16^{th} floor is the highest floor that the fire department can reach through ladders. Unlike in countries where refuge area is required for every certain number of floors, such is not the case in Korea. Also, many of the high-rise buildings also extend down to the underground floors which usually have a limited egress routes. With the nature of such buildings in Korea along with its expanded capacity, fire safety is a task that must be addressed. (Hong, 2009).

2.2.1.2 Economy

In 2010, South Korea ranked as the world's 15^{th} largest economy according to the gross domestic product (GDP) report released by the International Monetary Fund (IMF). South Korea is currently identified as one of the G-20 major economies and a member of Organization for Economic Co-operation and Development (OECD).

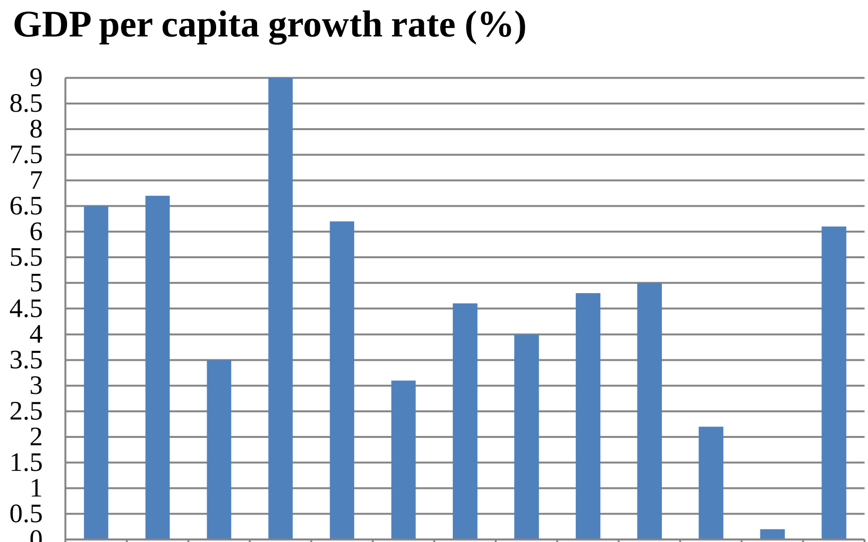
Despite the growing economic prosperity today, Korea had gone through times of trials and tribulations in the early 1900's. A weak Korea was open to incessant Japanese and Western encroachment from the end of the 19^{th} century. Japan had formally annexed Korea in 1910. The Japanese colonization came to an end after 36-years as Japan surrendered after the World War II defeat in 1945, but as a result Korea was left divided at the 38^{th} parallel with Soviet troops commanding the North and American troops commanding the South. The Korean War broke out on June 25, 1950 and lasted for 3 years leaving great damage and property loss. (CIA, 2011).

South Korea was able to stand up from the rubble of the Korean War through rapid economic growth. Starting from the 1960s until the 1990s South Korea had one of the fastest growing economies in the world. From 1960 to 1990, the average nominal GDP growth rate was close an annual increase of 23%. The real GDP growth, disregarding the price increases during the span of time, results in a substantial value of over 8%. (Harvie & Lee, 2003).



	1960	1970	1980	1990	2000	2010
GDP per capita (US $)	1877	3263	5551	11398	18755	30000

Figure 4: GDP per capita of Korea (Global Finance, 2011)



	1979 - 1990	1990 - 1995	1995 - 2000	2000	2002	2003	2004	2005	2006	2007	2008	2009	2010
GDP per capita growth rate (%)	6.5	6.7	3.5	9	6.2	3.1	4.6	4	4.8	5	2.2	0.2	6.1

Figure 5: GDP per capita growth rate in Korea (Korea's Economy, 2010)

With limited natural resources, a small domestic market, and low domestic savings, Korea relied on foreign investment and labor-intensive manufactured markets to stimulate economic growth. Automobile, shipbuilding, armament and electronics were the major industries leading the growth of Korea's export-oriented development. The economy today is still growing rapidly. In 1980, South Korean GDP per capita was only $2,300, comparable to the poor countries of Africa and Asia. However, the rapid economic growth has assisted achieving a GDP per capita of $30,000 in 2010. During the same time frame, the GDP has increased from $88 billion to $1,460 billion. (Korea's Economy, 2010).

2.2.1.3 Infrastructure

After the war, the 1950s and the 1960s were a period when the construction industry performed a lot of restoration work and took on numerous infrastructure projects. As a result of the Korean War, the entire nation except for Busan, the most southern city in Korea, was destroyed. The 1950s and 1960s was a period when a lot of expressways, railways, dams, seaports and airports were built, setting a solid foundation for the future economic growth. (CIA, 2011).

With an established solid infrastructure aided by both urbanization and economic development, Korea has had the honor to host a myriad of mega scale global sporting events in the past and will host many more in the years to come. With a host of nations entering a bidding war to host such prestigious events, it isn't common to see one nation rack up so many wins in the bidding war. Korea was host to the 1986, 2002 Asian games, 1988 Summer Olympics, 2002 FIFA World Cup (jointly hosted with Japan) and the 2011 IAAG World Athletics Championships. Korea has also won bids to host the forthcoming 2014 Asian games and the 2018 Winter Olympics. A meticulous analysis is performed by the members of the committee from each of the respective events to judge whether a country has the sufficient infrastructure and the sporting event sites to successfully host these events. It is no coincidence then that Korea only started hosting these events from the 1980's, a time when Korea was going through rapid transition in terms of infrastructure development. (Oh, 2011). The host nation is responsible for providing sufficient lodging, sporting event sites and means of transportation from and to sporting event sites. As a result, coordinating for one event may require building numerous stadiums and large scale hotels which may be complex in design.

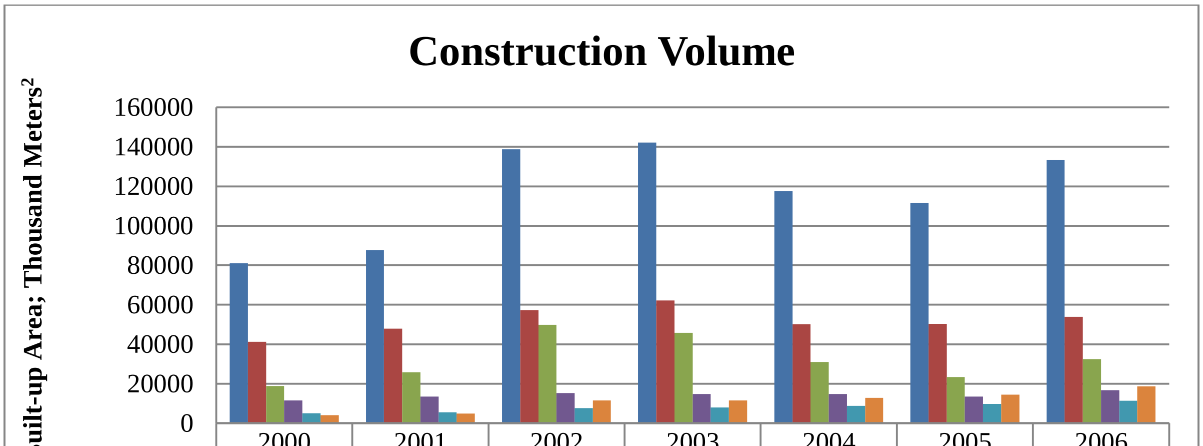
Figure 6: The Seoul World Cup Stadium which was completed and opened in 2001 before the kick-off of the 2002 World Cup (Seoul World Cup Stadium)

2.2.1.4 Construction Sector

In the 1970s, with the take-off of the industrial sector, the construction industry was also busy getting involved in building plants, industrial factories and commercial buildings.

The Korean construction companies were not limiting their projects to the domestic market and winning bids overseas as well. The construction has been a significant export market for Korea from the 1960s. A critical source for attaining foreign currency, the Korean construction companies reached new heights as 60 percent of the work Korean construction companies had undertaken in 1981 was all overseas projects. Overseas projects accumulated for a total sum of $13.1 billion. Contrastingly, in 1988, all overseas projects accumulated for a sum of only $2.6 billion. The significant reductions on overseas project contracts were due to the shift of focus as Korean construction companies were heavily involved with the domestic construction market driven by the rapid economic growth during the late 1980s. (South Korea Construction, 1990).

Korea was in desperate need of more housing by the 1980s. The overall population had gone from 24.9 million from 1960 to 37.4 million by 1980. At that same time, the urban population as a percentage of the total population more than doubled going from 27.7% to 56.7%. Rapid economic growth was also driving rapid urbanization in Korea. The construction industry took place as demand for housing significantly increased. From 1973 to 1982 only 196,000 houses and apartments were built annually on average. However, that number had exponentially grown to 750,000 in 1990. (Korea, South, 2012). The growth in the construction sector can be seen by the increase in the number of employees. Only 280,000 workers were employed in the construction industry in 1970, which accounted for 2.9% of the total employment. That number has gone up to 1.7 million by 2002 (accounting for 7.4% of total employment) and 1.9 million by 2008 which made up roughly 9% of the total employment. (Kelly & Herring, 2009).



	2000	2001	2002	2003	2004	2005	2006
Total	81058	87717	138734	142108	117461	111506	133271
Residential	41283	47856	57320	62128	50099	50281	53861
Commercial	18882	25888	49862	45809	30966	23368	32570
Industrial	11646	13538	15366	14738	14740	13579	16813
Educational	5126	5534	7604	7919	8860	9862	11340
Others	4121	4901	11513	11513	12796	14419	18687

Figure 7: Construction volume in Korea (Moon & Yoo, 2007)

Korea's limited usable land area means the construction market is bound to become saturated and limit opportunities to many of the companies in the growing construction sector. As a result, more Korean companies have found winning projects easier overseas and have started turning towards overseas construction projects.

Korean construction companies have set new heights in the global construction industry. Samsung Construction Corp was involved in all three of the world's top three highest buildings such as the Petronas Twin Tower in Malaysia, the TFC 101 Tower in Taiwan and the Burj Dubai Tower in UAE.

The Burj Dubai Tower was significant not only because it is the world's tallest building currently standing at 2723 feet but because it was the first time Samsung Engineering Corp was the primary contractor for the building. (Cho, 2007).

Figure 8: The Burj Dubai Tower in U.A.E (Burj Khalifa Building)

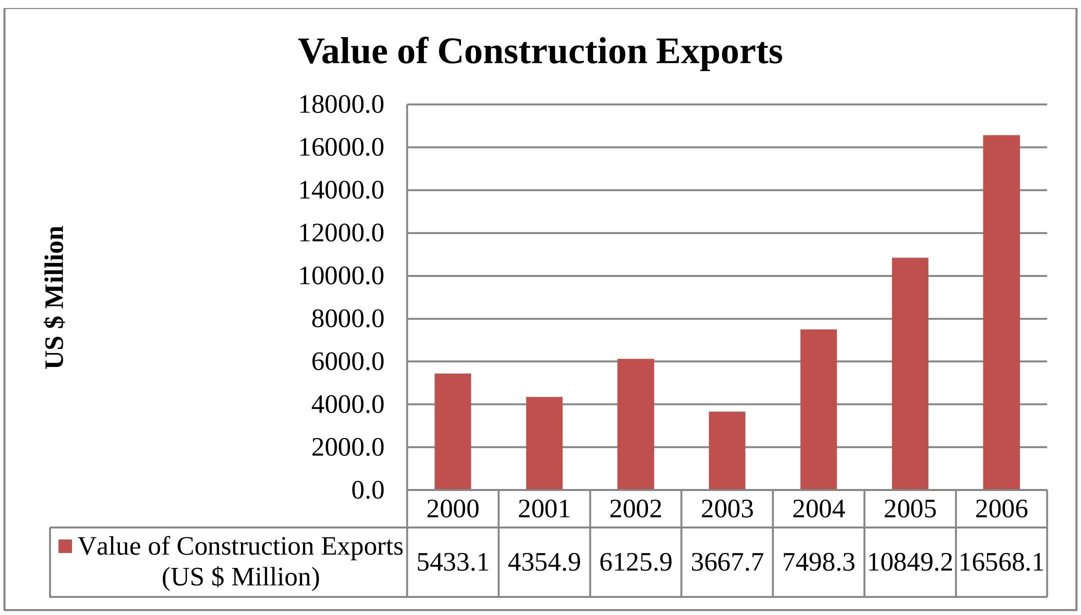


Figure 9: Construction export value by Korea (Moon & Yoo, 2007)

To further enhance and distinguish Korean construction companies in terms of competitiveness of technology, the Korean government has established the goal of construction and transportation for the future. Some of the goals include ranking inside the top 7 in the world by 2015 in terms of construction technological standards, reducing construction costs by 10% and occupying at least 10% share of the foreign construction market. To meet these goals, the Korean government has expanded its research budget on construction and transportation. (Moon & Yoo, 2007).

2.2.2 Building and Fire Code Policies

2.2.2.1 History of Fire Codes

After becoming a Japanese colony in 1910, the field of fire safety in Korea started developing rapidly. In 1925, the first ever fire department was installed. Near the end of the Japanese colonization era in the 1940's 50 fire departments were established nationwide. The 68 fire brigades in 1910 had expended to 1398 brigades by 1938, with 69,414 active firemen. Upon Korea's independence the peninsula was divided in two with South Korea being administered by the United States. In 1946 a national fire committee was formed along with municipal fire departments. On April 10th, 1946, the fire department separated away from the police department. (Hong, 2009)

On October 11th, 2002 the Fire Services Act was requested to be divided into four categories that consisted of Fire Safety Act, Fire Protection Systems Construction Act, Fire Protection Systems Installation and Management and Safety Provisions Act, and Hazardous Material Management Act. After rigorous discussions and reviews of the proposal from February to April of 2003, the proposal came through. As of May 30, 2004, the Fire Services Act has been abolished. This division of the was inevitable. Since its enactment till abolishment from 1958 to 2004, the Fire Safety Act had gone through 25 revisions. On average that meant a revision occurred every two years. Despite the rapid changes in the fire safety circumstances aided through the economic growth, the fundamental base system of the Act was kept intact. Only slight alterations were made to accommodate for needs after the occurrences of big fire disasters such as the Daeyeongak Hotel (detailed story included in Appendix A.5) or when a change in political power had occurred. The Fire Services Act included everything that is related to fire safety, which often times led to readers being unable to comprehend the regulations completely in order to comply with the regulations. This division of the Act into four separate distinctive categories was executed in hopes that people would easily fathom the codes and comply with it. (Hong, 2009). The Acts are broken down in detail and activities included in each Act can be viewed in Appendix A.

2.2.2.1 Uniformity in Codes

Korea has one national fire code established by the National Emergency Management Agency and one national building code established by the Ministry of Construction and Transportation Authority. Korea is divided into 9 provinces. (Kang, Kim, & Kim, 2007).

Considering how Korea is only one quarter the size of the state of Indiana, having one national fire code throughout the entire nation seems practical. All of the provinces share a similar climate and architectural style. The entire Korean peninsula has distinct seasons in spring, summer, fall and winter. Summer season can be characterized as hot and humid with a short monsoon season during the months of June to July and the winter season can be characterized as extremely cold with snow. (Climate of Korea). Most of the architecture in Korea consists of the traditional Korean houses with curved tiled roofs called 'Hanok', westernized structures and high-rise buildings. Without such provincial variances, having different fire codes for every province would be impractical. As mentioned previously, with a lack of uniformity between the separate building and fire codes causing conflicts, having several provincial codes for each of the provinces would only add more fuel to the fire. (Hwang, 2009).

There have been difficulties and confusion in attempts to comply with the regulations in the construction sector. A building must satisfy both the building code and the fire code in Korea. The fire code includes most of the clauses on active fire protection systems while the building code includes most of the clauses on passive fire protection systems. However, these set of codes are separate and because they are managed by two different organizations, there are many grey areas that need to be cleared up. The table below shows the overlapping areas between the fire regulation and the building regulation. (Seo, Kim, Hwang, & Kwon, 2009). There are overlapping areas between the two set of codes and it is easy to confound the readers. One of the issues that have led to such confusion is that there are disparities in the word definitions between the two set of regulations. Table below shows how the word definitions are defined differently in each set of regulations.

Table 3: Overlapping terms between Korean building and fire codes

Regulation	Term	Definition
Fire Regulation	Evacuation System	Slides, ladders, rescue work tools, emergency lighting and sign, taxiway light
	Suppression System	Fire suppression tools, fire hydrant (inside building), sprinkler system
Building Regulation	Egress System	Corridor, staircase, exits
	Suppression System	Fire hydrant, water tank

Due to such problems it has been pointed out by many that uniformity between the fire and building code needs to be established. In 2010, such attempt took place. The building code regulators, Ministry of Construction and Transportation Authority, proposed to the fire code regulators, The National Emergency Management Agency, to combine the two regulations into one uniform regulation. This ambitious plan fizzed out and no agreement between the two parties was made. Besides putting up the proposal, nothing concrete has occurred ever since in terms of combining the two regulations. However, both parties have been working hard to minimize the discrepancies between the two regulations. Through these continuous efforts, the discrepancies between the two regulations are closing down on the gap. (Choi, 2011).

2.2.2.2 Code Development

Until now, politicians and the mass media have shunned their interest or stayed apathetic from the issues of fire safety. Fire safety has long been ignored. It has been that only after a big fire disaster had occurred that the politicians and the mass media turned their attention to fire safety and acted as they truly cared. Even during the aftermaths of such calamitous fire disasters, the politicians have been busy pointing their fingers at national fire officials as the ones to blame or that stricter regulations must be placed established rather than trying to implement sufficient measures to effectively tackle the problem from the grassroots level by providing the necessary backing, funds and research efforts. (Hong, 2009). However, Korea took a step closer to successfully transitioning to PBD. Performance based design codes were enacted on January 1st 2009 after several years of careful consideration of the method. Performance based design codes are included under the Fire Safety Construction Act. At first performance based design regulation was supposed to come in effect within a year after the Fire Protection Systems Installation and Management and Safety Provisions Act became effective. However, no decision could be made on setting the regulations for which buildings would be subject to performance based design and who would be the qualified or licensed candidate allowed to handle the task. Article 2 clause 2, which lists the buildings subject to performance based design and Article 2 Clause 3, which lists the personnel who are eligible to carry out performance based designs, were inserted to the Fire Safety Construction Act on January 24th 2007. This allowed performance based design to finally become effective as of January 1st 2009. (Baek & Yi, 2010).

2.2.2.3 Implementation of Codes

According to the Building Regulation, building permits are regulated by The Fire Protection Systems Installation and Management and Safety Provisions Act. All the required procedures for getting a prescriptive based design approval are included in Article 7 of The Fire Protection Systems Installation and Management and Safety Provisions Code. According to the building regulation, all items pertaining to building permits and legislative approval are included in included in the Fire Protection Systems Installation and Management and Safety Provisions Act. These codes, included in Article 7 of The Fire Protection Systems Installation and Management and Safety Provisions Code, are for prescriptively designed buildings so a clear regulatory system on the legal procedures of obtaining building permits for buildings designed based on performance codes that are regulated by the Fire Safety Construction Act, needs to be established. (Baek & Yi, 2010).

The legal nature of obtaining a building permit as stated in the Fire Protection Systems Installation and Management and Safety Provisions Act is problematic. The procedure of getting a fire safety design approved requires submitting a fire safety design plan of a structure to the government office. The government office will then transfer the fire safety design and all documents related to the fire safety design to the head of the fire department under the jurisdiction. The head of the fire department will review the documents send the files back with comments on it to the government office. The building officials need to apply for building permits only to the government office not the fire department. So in essence the head of the fire department does not have the authority to rebuke the application. The decision made by the head of the fire department is only considered to be a negotiating process with the government officials. (Baek & Yi, 2010).

The building permit regulation is specified in Fire Regulation, and the Building Code does not contain any clauses that the building permit should be permitted by the head of the fire department. Therefore, any construction that has not been reviewed according to the appropriate procedures could cause problems and the effectiveness of the building permit approval could come to question in reality. In other words, the shortage of the law on granting building permits could be a defect of the legal proceedings that is defined by the law. In this case, the building permit approval or permission for its usage becomes subject to discussion. (Baek & Yi, 2010).

2.2.3 Education and Market Capacity

2.2.3.1 Fire Protection Engineering Programs

Currently, there is no educational facility or program that touches on the topic of fire dynamics, which is an essential course that teaches one to understand and calculate specific characteristics of a fire in certain boundary conditions. In Korea, there exist as many as 70 departments within universities or community colleges that offer programs in fire safety courses minus the fire dynamics. (Choi, 2011).

2.2.3.2 Current Situation of Fire Protection Engineers

Although PBD codes have been enacted since January 1st, 2009, ‘fire protection engineer’ is a term that still does not exist in Korea. Currently, due to the lack of fire protection engineers, most of the PBDs are currently being conducted by PE certified engineers, who mostly base their judgments based on knowledge gained from previous experiences. The only real fire protection engineers present in Korea are only those who have received education abroad. (Choi, 2011).

2.2.3.3 Market and Regulatory Needs for Education

As stated previously, Korea will keep growing vertically. With plans in place for even more high-rise and complex buildings, the construction market will definitely generate great opportunities to fire protection engineers as PBD codes require buildings of more than 30 stories high to use PBD. Although such jobs are being taken on by PE licensed engineers and foreign educated Korean fire protection engineers, the number is not enough. (Choi, 2011).

2.2.4. Summary

Korea has seen great development in multiple areas over the past couple of decades. Economic activities in this small country have led to an urban sprawl in the cities and along with the population growth. Korea has become one of the most densely populated country in the world. Since the 1980’s, Korea, especially in the urban areas, has grown vertically to accommodate for housing demand. Whereas Koreans were only focused in gaining economic benefits in the 1970’s, great economic development and rise in the standard of living have given them the luxury to contemplate and ponder issues of safety. Korea has already established a solid urban environment where transitioning to PB fire codes has become inevitable with the majority of the buildings in Korea already being high-rise or large and complex. With countries such as Australia, Japan, New Zealand, Scotland, Spain and United Kingdom already having set the global trend of transitioning to PB fire codes, Korea has followed up by introducing a set of PB fire codes into its previously prescriptive fire codes in 2010. Although this was a step forward, Korea must not forget that the job is not complete and there are areas that need more development. With a separate national building and fire code, the set of two codes should either be combined in to one document or the gaps and disparities between the two should be revised. Also, it is essential the fire protection engineering programs be established to nurture and produce highly qualified fire protection engineers. Without their expertise of predicting how structures would behave under certain fire conditions and risk analysis skills, the potential of PBD will not be exploited at full potential.

2.3 Poland

2.3.1 Urbanization

2.3.1.1 Urban Settings

Poland's tumultuous renaissance was provoked by its desertion from the Soviet Union in 1989 when the country gained its independence. The subsequent powerful "political transformation" dramatically assisted in eliminating many of the communist features from Poland's urban centers. Poland received another energizing shot to its economy with the country's accession into the European Union and subsequent introduction to the global market economy. As Poland develops a new economy, urbanization has become defined as the trend of citizen migrating from the massive rural areas of Poland to the urban epicenters of the country. This migration has been complimented by the assimilation of rural people to the urban way of live and occupations. The infant global market economy has created competition between the Poland's cities, with the more economically developed urban centers being increasingly attractive to people migrating from rural zones. The most attractive of these urban areas for migration and foreign investment are Warsaw, Poznan, Wroclaw, Krakow, and Tricity. (Polish Background Report: For OECD National Urban Policy Reviews in Poland, 2010)

Geography also contributes to the current urbanization trends, with greater economic growth of metropolitan areas occurring in the western area compared to the eastern area of Poland. This trend is due to several urbanization trends including the faster development of western suburban zones than eastern suburban zones. Western cities have established a stronger connection between its medium sized cities along with relatively more migration from smaller western cities to larger western cities. On the other hand, the urban areas of eastern Poland has experienced a more traditional urbanization process as rural inhabitants move to the cities of that region. (Polish Background Report: For OECD National Urban Policy Reviews in Poland, 2010)

Based upon numbers from 2008, there are 8925 towns incorporated in Poland. This figure, which includes the nation's cities, is comprised of 17 "towns" with more than 200,000 resident, 5 “towns” with more than 500,000 residents (Warsaw, Krakow, Lodz, Wroclaw, and Poznan), 5 “towns” with between 300,000 and 500,000 resident (Gdansk, Szczecin, Bydgoszcz, Lubin, and Katowice), and 7 “towns” between 200,000 and 300,000 residents (Bialystok, Gdynia, Czestochowa, Radom, Sosnowiec, Torun, and Kielce). The combined population of these 17 “towns” or cities comprises 20.8% of Poland’s national population. Unlike the majority of the countries of the European Union, the population distribution of Poland is not drastically disturbed by its capital city, Warsaw. Warsaw is inhabited by only 4.5% of the country’s population, a fact which may be attributed to the country’s great land mass. The population distribution is more affected by geographical trends, with the western urban centers being more densely populated than eastern urban centers. (Polish Background Report: For OECD National Urban Policy Reviews in Poland, 2010)

From the decade spanning between 1988 and 1998, the Polish urban population increased by approximately 495,200 people while the Polish rural population decreased by approximately 102,900 people. In the decade which followed, from 1998 to 2008, the urban migration trend was reversed as urban population numbers decreased by 393,000 residents and the populations of towns increased by 252,700 residents. The statistics of these two decades are not comparable because the entire population of Poland decreased by 141,100 people between 1998 and 2008 because of international emigration. (Polish Background Report: For OECD National Urban Policy Reviews in Poland, 2010)

Since the beginning of 2008, the population decline in Poland has halted. In the first 18 months since the beginning of 2008 the population of Poland has increased by approximately 37,400 inhabitants. The greatest of this population growth occurred in a small number of urban, urban/rural, and rural gminas (communities) which are located within the limits of Poland’s largest cities. (Polish Background Report: For OECD National Urban Policy Reviews in Poland, 2010)

Suburbanization, the development of suburban zones, is considered an aspect of urbanization. Suburbanization is often a by-product of urbanization, as large numbers of people migrate to urban centers to gain employment. However the cities are often not prepared for the influx of resident and migrates are forced beyond city limits to secure affordable housing options. Suburbanization plays a crucial role in the process of urbanization in Poland’s metropolitan areas. Between 1988 and 2007, for Polish cities which registered a drop in population, the adjacent gminas to the respective cities reported a dramatic influx of residents. (Polish Background Report: For OECD National Urban Policy Reviews in Poland, 2010)

One of the negative by-products of dramatic urbanization can often be poverty and substandard living conditions. While Poland has experienced great economic growth in the past decade, poverty statistics seemed to lag behind the development. Persons at risk of poverty in Poland jumped from 9.5% in 2001 to 12.3 % in 2005. However in recent years, the polish standard of living has begun to catch up as the percentage of people at risk dropped in Poland to 5.6% in

2008. The majority of poverty in Poland is concentrated in rural regions. It seems as though urbanization has had a positive effect upon poverty numbers. Illustrated by the trend that the larger the city in Poland, the smaller proportion of people living below the standard of living. (Polish Background Report: For OECD National Urban Policy Reviews in Poland, 2010)

The areas of Polish cities which require the most amount of gentrification are usually the high density apartment neighborhoods and industrial zones. More often than not these areas are remnants of the Soviet era. However unlike many former countries of the Soviet Union in Western Europe, Poland's culture does not contain any racial or religious segregation. Segregation based upon social economic classes is prevalent in Polish cities. (Polish Background Report: For OECD National Urban Policy Reviews in Poland, 2010)

Several factors must be taken into considering while analyzing the population distribution numbers outlined above. Of these factors, the most influential is the large percentage of the people moving from rural to urban zones in Poland who go unregistered. (Polish Background Report: For OECD National Urban Policy Reviews in Poland, 2010)

2.2.1.2 Economy

The international stereotypical image of Poland is that it is nothing but a large, poor land, lingers from the days of the country's communist occupation (Horse Power to Horspower). However this could not be further from the truth as Poland is emerging as one of the fastest growing markets in Europe. After gaining independence from the Soviet Union in 1989, Poland's economy remained stagnant in post-communist confusion, but the Polish market was jumpstarted by the country's acceptance into the North American Treaty Organization (NATO) in 1999. Poland gained further financial momentum after joining the European Union in 2004. Poland's economy has developed into a high- income market, ranking as the sixth largest in the European Union (Country and Lending Groups, 2010). As a matter of fact it is the only country in the EU to not only register positive economic growth in the 2006 at 1.2% but also evade decline in the national GDP (Polish Information and Foreign Agency, 2007). In 2009, the Polish GDP per a capita rose from 50% to 56%% of the European Union's Average, a record jump for the country's short but promising history in the EU. Currently Poland holds the 20th highest GDP worldwide (Skolimowski & Burg, 2009). Much of the recent economic success listed above is due in large part to Poland's recent addition to the European Union and the country's "stodgy" national banks missing the boat on the overzealous "foreign currency lending" trend which sunk the economies of close-by Latvia and Hungary (Horse Power to Horspower). In terms of politics, Poland maintains a "center-right government with a majority in parliament," which is hard to come by in countries of its kind (Pleitgen & Davies, 2011). All of these factors combine to project a very promising economic future for the once grim nation.

Foreign investors are intrigued by some of Poland's most fundamental attributes, believing the country possesses great market potential in the future. The great political, social, and economic stability of Poland eliminates a great level of intangibles which could cause foreign investors to be apprehensive about investing within Polish borders (Horse Power to Horspower). Poland has developed into the most dynamic economy in the EU, having transitioned from an atmosphere of persistent unemployment to an atmosphere of seemingly unbounded job creation, causing a great demand for manpower (Pleitgen & Davies, 2011). This promising evolution has produced not only one of the European Union's largest but also least expensive workforce. The great international demand for renewable energy will assist in sustaining Poland's economic growth as the Polish renewable energy sector possesses huge potential in the future because of the country's rich natural resources (Torbellin, Patricia, Torres, & Judith, 2009). A third of Poland's land mass contains untapped geothermal water which is equivalent to 3.5 billion tons of oil, the richest deposit of the resource in Europe (Torbellin, Patricia, Torres, & Judith, 2009). Additionally, the country is blessed with a multitude of large rivers which hold great hydroelectric power potential. The land of Poland is also rich in minerals such as coal, copper, lead, and sulfur along with valuable rocks necessary for producing construction materials (Torbellin, Patricia, Torres, & Judith, 2009). The KYOTO Protocol, an international environmental agreement requiring all member states to acquire 25% of their total energy needs from renewable sources, represents an ever-growing market trend towards renewable energy that Poland, utilizing its wealth of natural resources, will most certainly capitalize upon in the near future (Torbellin, Patricia, Torres, & Judith, 2009). With a solid foundation and a very promising future, the Polish economy should not only sustain its unique economic growth but also continue their upward swing of financial development by attracting increased foreign investment and exploitation of their vast yet untapped natural resources (Torbellin, Patricia, Torres, & Judith, 2009).

2.3.1.3 Infrastructure

The past decade has provided Poland with an excellent foundation for economic development. The future holds great potential for the Polish market, but the future level of financial success will depend, largely in part, upon how heavily the country invests in its outdated national infrastructure system (Banjanovic, 2007). One of Poland's most valuable natural resources is its geographical location, acting as a literal bridge between the more advanced Eastern European market and the struggling Western European countries (Banjanovic, 2007). Currently, Poland's road system is one of the worst in Western Europe with only 3% of roads meeting the standards set by the European Union (Banjanovic, 2007). The low road network density, 1.19 km per square km along with congestion caused by increased automobile flow has slowed down the movement of people and goods thus threatening to stall the economic momentum (Banjanovic, 2007).

However great strides have already been made to improve the Polish Infrastructure as the EU has increased structural funding in the country from 2007 to 2013, produced from the EU Structural and Cohesion Fund which is designed to update transport networks, increase regional development, and promote education and environmental causes. Enhanced infrastructure would allow commodities to reach overseas markets faster while reducing costs, thus spurring economic growth for exports make up a majority of the country's GDP. (Banjanovic, 2007) Although Poland only had 600 kilometers of roads in 2007, over 900 kilometers were planned to be built by 2012. Additionally, there are plans going into action for improvements in the water treatment system and public transportation. The most important of the public transportation projects being the addition of a second metro line in the capital city of Warsaw along with the renovation of 52 train stations. While Poland has a long way to go in terms of national infrastructure, the country has made improvements in some areas. Poland will be co-hosting the UEFA Euro 2012 soccer tournament with the Ukraine. In anticipation for the event, a large scale effort has been launched across the nation to construct new stadiums and renovate pre-existing stadiums, such as the 56,000 seat National Stadium in Warsaw. (Chelminski, Warsaw on the Rise, 2011)

2.2.1.4 Construction Sector

The economic boom in Poland has not only lifted the shroud surrounding the country but also stimulated the national building industry which is crucial sector of the country's economy. Construction companies have become much more optimistic in their assessment of the current market environment. Nowhere is this trend more evident than in Poland's official capital, Warsaw. Warsaw is not only the largest city in Poland, acting as a catalyst for the once-rural country, but also the 9th largest in the European Union in terms of population. The city is often called the "phoenix city" as it rose from the ashes, like the mythical fire-bird, after Adolf Hitler burned over 85% of the city during his occupation in World War Two. Poland has invested massive amounts of funds into the country's once delay-plagued infrastructure network, further enriching the environment for foreign investments (Attracting Foreign Investment, 2004).

The development of the commercial real estate sector in Poland was provoked by the economic growth of the country. Subsequent to the admission into the European Union, Poland received a large inflow of foreign capital which fueled the development of real estate and industrial growth. An example of this trend is the substantial profits on recently bought commercial properties in the years following 2004 (Masztalski & Michalski, 2011). Development in the business sections of Poland's urban centers was driven by a lack of commercial properties, as buildings were constructed to accommodate the emergence of international companies such as Bridgestone.

Foreign investors clamored for properties in Polish cities such as Wroclaw, which is adjacent to main roadways connecting the country with western Europe. Cities such as Krakow and Warsaw were sought after because of large populations of well-educated and highly-skilled Polish citizens. Finally, regions located in the middle of the country such as Lodz were attractive to Foreign Investors because of their centralized positions and well-educated workforces. (Masztalski & Michalski, 2011)

Foreign investment spurred by admission into the European Union was not restricted to the commercial sector. The residential property sector also demonstrated great growth as the communist housing co-operatives were replaced by up to date options (Polish Background Report: For OECD National Urban Policy Reviews in Poland, 2010). This trend has caused the construction industry to shift from an investors market to a contractors market, as the price of contractors rose 20% from 2005 to 2007.

Warsaw is considered the "tallest city in Europe" with 18 of Poland's 21 skyscrapers within the city limits. Additionally the city has Construction is also underway in building and renovating soccer stadiums across the country, including the 56,000 seat National Stadium in Warsaw, in preparation for the UEFA Euro 2012 soccer tournament which Poland is hosting along with the Ukraine (Attracting Foreign Investment, 2004). The largest skyscraper construction project currently underway in Warsaw is Zlota 44, a 54 story luxury residential building. Zlota 44, named after the structure's pre-war address, was designed by acclaimed, Poland-native Daniel Libeskind as a symbol of the resiliency of the Polish people (Chelminski, Warsaw on the Rise, 2011). Located in an area of Warsaw completely demolished by Adolf Hitler, Zlota 44 will be the 3rd tallest skyscraper in Poland upon completion.

2.3.2 Building and Fire Code Policies

2.3.2.1 Uniformity in Codes

The ever developing country of Poland is divided into sixteen voivodeships or provinces. In the past, these voivodeships were based upon the adjacent urban center, the borders of Poland's current voivodeships are founded upon the country's established historical regions. Poland is the 9th largest nation in continental Europe and the 69th largest country in the world with a total area of 312,679 square kilometers. The currently established voivodeships vary in area by approximately 25,000 square kilometers with the largest being the Masovian Voivodeship (35,000 square kilometers) and the smallest province being the Opole Voivodeship (<10,000 square kilometers). The provincial governmental system is composed of a nationally appointed governor (voivode), an provincial assembly (sejmik), and an assembly appointed executive. (Polish Background Report: For OECD National Urban Policy Reviews in Poland, 2010)

Each Voivodeship is partitioned into counties (powiats) and further subdivided into gminas (communities). Poland's largest urban centers are considered both a gmina (community) and a powiat (county). The sixteen voivodeships of Poland are subdivided into 379 powiats and 2,478 gminas. (Polish Background Report: For OECD National Urban Policy Reviews in Poland, 2010)

Based upon the facts above, one would think that the geographical giant country of Poland would be more redisposed to a state or regional based fire safety code system. However Poland's fire protection codes are based upon a national fire safety code system. The national fire safety regulations are divided into two individual documents, The Building Regulations and the Fire Safety Act. (Tofilo, 2012)

The Building Regulations Act (Parliament Act- Ustawa Prawo Budowlane) is a general act which contains technical requirements for the construction of buildings and their surroundings. The Building Regulations Act contains delegation for creating an Infrastructure Minister's Decree known as The Technical Requirements for Buildings and their situating (Warunki Techniczne dla Budynow I ich Usytuowania which is a more detailed prescriptive code for the construction of buildings. The Technical Requirements for Buildings article contains a chapter on fire safety and protection. Within the fire safety and protection chapter are the sections: General, Fire Resistance of Buildings, Fire Compartments and Fire Barriers, Evacuation Routes, Internal Finishing and Fixed Elements, Installations and Stoves, Building Situation, Garages, Farm Buildings, and Temporary Buildings. Also, a few additional fire- related issues are mentioned in other chapters. (Tofilo, 2012)

The Fire Safety Act (Parliament Act- Ustawa o Ochronie Pzeciwpozarowel), which complements The Building Regulations Act, outlines how the administrative structure and authoritative roles of fire safety are organized. The Fire Safety Act contains delegation for creating three Interior Minster's Decree's including: Fire Safety in Buildings, other Structures and Areas; Access for Fire Fighting Teams and Water Supply for Firefighting, and Approval of Building Designs in Terms of Fire Protection. (Tofilo, 2012) The most extensive of the three Interior Minister's Decree's is the Fire Safety in Buildings, other Structures, and Areas article which contains the following chapters: General, Forbidden Activities and Duties in Fire Safety, Dangerous Materials, Evacuation, Internal Fire Fighting Water Supply and Provisions, Fire Protection Systems, Technical Systems and Appliances, Fire Safety Precautions during Maintenance Work, Fire Protection of Forests, Fire Precautions in relations to Crops. (Tofilo, 2012)

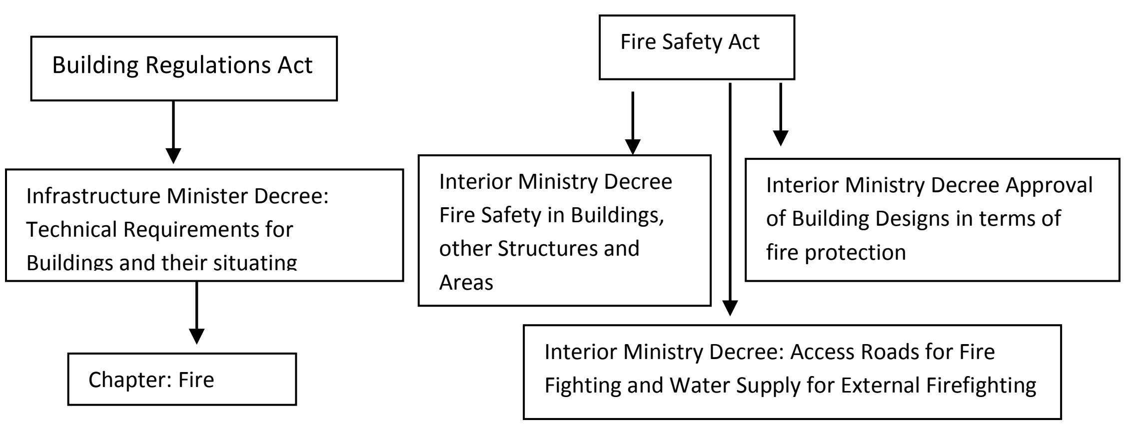


Figure 10: Courtesy of Dr. Piotr Tofil (2012)

2.3.2.2 Code Development

The Building and Fire Safety Acts outlines above are managed by the former Ministry of Infrastructure. The Ministry of Infrastructure was an agency originally created in October of 2001. However the Ministry was later reorganized into the Ministry of Transport and

Construction under the “Law and Justice” governmental plan of Kazimierz Marcinkiewicz (Zajac, 2009). The Ministry of Infrastructure was re-formed in 2007 under newly elected Donald Tusk. The Ministry of Infrastructure remained until 2011 when Council of Ministries once again abolished the ever-changing Ministry and replaced its presence with the Ministry of Transport, Construction and Transport Economy and the Ministry of Interior and Administration. Changes to Building and Fire Safety regulations must first be approved by the Polish Parliament (Zajac, 2009). Usually the approval of revisions comes in a series of approvals by the Parliament. The Ministry of Transport, Construction and Transport Economy (Ministry of Infrastructure) often signs secondary legislation which results from the revisions or a new act. Additionally the Ministry of Transport, Construction and Transport Economy (Ministry of Infrastructure) often performs analysis on required changes to regulations subsequent to the revisions or implementation of a new act (Zajac, 2009).

The Ministry of Interior and Administration and the Ministry of Transport, Construction and Transport Economy both handle the legislative aspect of fire safety in Poland (Zajac, 2009). The Ministry of Interior and Administration has passed two Ordinances in recent years concerning Polish fire safety. The first ordinance which was passed on October 24, 2005, concerned fire protection inspections and included extensive occupation requirements for the individuals preforming the inspections. The second ordinance passed by the Ministry of Interior and Administration on April 21, 2006 was in reference to the fire protection engineering of all buildings, structures, and all other areas.

The Polish State Fire Service works in conjunction with the Ministry of Transport, Construction and Transport Economy (Ministry of Infrastructure) in matters of Fire Safety. The regulatory authority of the Polish State Fire Service is broken into three administrative levels which follow the nation’s administrative system (Zajac, 2009). There is one national headquarters along with sixteen provincial headquarters for the Sate Fire Services. Within the 16 provinces of Poland are 335 District Headquarters and 499 fire-fighting rescue units (Zajac, 2009).

The State Fire Service has a complex organizational system which includes all aspects of fire safety. The District Headquarters of the State Fire Service is mainly involved with “Hazard Recognition” which deals with fires and other threats. The District Headquarters of the State Fire Service also acts mainly as the supervision authority for “Fire Regulations Compliance” and shares responsibility for the “Supervision of Regulations Concerning Prevention of Major Accident Hazards” with the Provincial Headquarters of the State Fire Service. The main role of the Provincial Headquarters of the State Fire Service is the regulation of the “Building Design Acceptance Process,” which is where the waiver clause of the Building Regulation Act is taken into consideration. The “Building Design Acceptance Process” is an area where sufficient knowledge of the Performance-Based Design approach for Fire Protection Engineering will be crucial. Without extensive education in Performance-Based Design Approach, officials at the Provincials Headquarters will be unable to properly evaluate building plans which use the Performance-Based Design approach for fire safety. The Provincial and National Headquarters share responsibility for the "Hazard and Safety Analyses" of firefighting plans, "legislation process," and advancements in fire protection. The main role of the National Headquarter of State Fire Service is the certification and regulation of the country's "fire experts." Polish "fire experts" preform the tasks of fire protection engineers in the country. The regulatory system of the "fire experts" in Poland, is a rare attribute in the international community of fire protection engineers. (Zajac, 2009)

2.3.2.3 Implementation of Codes

Currently one of the largest issues which Poland has encountered while transitioning to Performance-Based regulations is lack of experience with Performance-Based design. Provincial Fire Brigade Fire Officers do not have sufficient training to properly evaluate Performance-Based designs. Because of this, the approval is more often than not based on trusting the specific engineer who prepared the Performance-Based fire report. In other cases approval of the Performance-Based fire report is based upon on simple checks relative to the Fire Officer's limited training. Both current insufficient approval procedures contributes to a low standard of Performance-Based Designs in less developed province. (Poland has 16 provinces) (Tofilo, 2012) In terms of the implementation of the EuroCodes, the building elements are used "relatively widely" by Polish civil engineers (Tofilo, 2012). However, Polish designers and fire protection engineers are less familiar with the fire safety aspects of the Eurocodes and therefore are hesitant to utilize them (Tofilo, 2012).

2.3.3 Education and Market Capacity

2.3.3.1 Fire Protection Engineering Programs

Poland is one step ahead of most countries in terms of educational programs to train fire protection engineers because of the nation's Main School of Fire Services. The Main School of Fire Services was established in 1971 to train fire safety engineers (Cisek, Skaznik, & Cisek). Even with an ever escalating international demand for engineers well versed in the field of fire protection, the Main School of Fire Services (MSFS) is one of only a handful in Europe. MSFS is the only institution in Poland which offers fire protection engineering courses. Students at the MSFS are taught the fundamentals of fire engineering such as the theory of fire and the theory of burning (Cisek, Skaznik, & Cisek). The curriculum of the school is focused upon teaching methods of meeting the fire safety requirements for Poland's current fire safety regulations which are extremely prescriptive in nature (Tofilo, 2012). While the MSFS is not completely converted to reflect the needs of Performance-Based Design, the curriculum is supplemented by "secondary practices" which include performance-based design tools. The performance-based branch focuses primarily on meeting required safety levels with alternative methods in such areas as risk analysis (Cisek, Skaznik, & Cisek).

The Main School of Fire Services plays a crucial role in the development and promotion of fire protection engineering in Poland. The Fire Protection climate in Poland is influenced primarily by the MSFS and the Association of Fire Engineers and Technicians (SITP). Not only does the Association of Fire Engineers and Technicians (SITP) advancing fire safety engineering, but the members of SITP act as liaisons with fire protection engineers worldwide (Ratajczak & Tofilo).

Poland's educational system has great potential to expand its capacity to educate fire protection engineers in country. The secondary education level in Poland is separated into two categories. Polish universities are oriented towards the liberal arts and have no engineering department. Secondary education for engineering is completed at separate technical institutions (Krasniewski & Woznicki, 1996). There are 22 engineering schools located in Poland, although only one is state owned. This presents a large problem because only state schools have free tuition. Many polish students interested in studying engineering are deterred by the financial expenses associated with attending one of Poland's private technical institutions (Krasniewski & Woznicki, 1996). The majority of Polish engineering students pursue a 5 year, 10 semester degree known as a "Magister Inzynier," which is equivalent to a master of science in engineering. A less extensive degree, known as a "Inzynier," is accomplished in 7 semesters. The "Inzynier" degree is equivalent to a bachelor's degree in engineering (Tofilo, 2012). The Polish engineering core curriculum contains a traditional skeleton of fundamental classes.

The volatile economic climate which was predicated by Poland's desertion from the Soviet Union had great effect upon the higher educational system in Poland. Technical institutions were among the worst hit because of the high expense of engineering courses compared to liberal art courses including the cost of equipment, computers, and laboratories (Krasniewski & Woznicki, 1996). In order to survive, many technical institutions underwent dramatic modifications including significant cost cutting, layoffs, and bolstering enrollment. In order to increase attractiveness of the study of engineering, institutions are becoming more flexible and compatible to international curriculums (Krasniewski & Woznicki, 1996). While no technical institutions in Poland possess fire protection engineering departments, some of the disciplines of engineering offered could assist in the development of such a program. Engineering concentrations offered in Poland such as computer architecture have direct application in fire protection engineering.

2.3.3.2 Current Situation of Fire Protection Engineers

The Country of Poland has an established system of private licensed "fire experts" who play a crucial role in the process of approving the fire protection aspect of a construction project's design. These "fire experts" are responsible for reviewing fire protection design and deciding if it is sufficient. Once the "fire expert" deems the fire safety level sufficient and the design receives approval, the specific "fire expert" informs the Fire Brigade Authorities of the ruling. (Tofilo, 2012)

In order to become accredited as a licensed "fire expert" one must pass a series of exams. Currently in Poland there are approximately 500 licensed "fire expert," of which only a fifth of this number grant approvals regularly, with the remaining eighty percent only performing the occasional approval. Of the twenty percent of licensed “fire experts,” only a small portion are actively attempting to comprehend and incorporate new methods such as Performance-Based Design and the “implications and uncertainties” which accompany any developing field. Additionally, there is a group of unlicensed “fire expert” engineers which strictly do the engineering work for designs without approvals. (Tofilo, 2012)

2.3.3.3 Market and Regulatory Needs for Education

The country of Poland would require both the short-term assistance of fire protection engineers and consultants to reform their National Technical and Building Regulations to be performance-based and long term employment of fire protection engineers to perform day to day tasks involved with performance-based regulations including examining design plans.

Even if Poland resisted a transition to Performance-Based Fire Safety Codes, there will still be an increase in the market and regulatory needs for the education of fire protection engineers. As the country’s economic growth fuels the construction industry, especially in the sector of large commercial properties and “prestigious buildings,” there will be more requests for the use of the Building Regulation’s waiver clause. In order to guarantee that the alternative design will provide the level of fire and occupant safety which the prescriptive codes require, the Performance-Based Design approach will be utilized. This ever increasing number of Performance-Based Designs will require more well-trained fire protection engineers to fabricate these PBD’s and subsequently more well-trained fire protection engineers will be needed at the Provincial level of the State Fire Service to evaluate these PBD’s.

2.3.4 Summary

The country of Poland is one of great potential for years to come in all three areas of driving factors listed above. This high potential translates to continued progress in the country’s effort to transition to a Performance-Based code system. Sustained economic growth of the country will bolstered by increased foreign investment because of Poland’s prime geographic location, natural resources, and multi-faceted stability. This sustained economic development throughout the country of Poland will continue to stimulate the construction industry in the form of “prestigious buildings,” which will require more advanced fire safety codes in order to make their construction realistic and economically feasible. This industry strain will create an increased demand for Performance-Based fire safety codes, subsequently accelerating the development of Fire Protection Educational programs which include Performance-Based Design fundamentals in their curriculums. These secondary-education programs which teach the Performance-Based Design approach will increase both market and regulatory levels of experience with Performance-Based Design. The more comfortable Polish professionals in the fire protection field become with PBD, the more feasible and effective national Performance-Based fire safety codes become.

2.4 Brazil

2.4.1 Urbanization

2.4.1.1 Urban Settings

The Federative Republic of Brazil has an estimated area of 8,311,965 square kilometers (sq km) and consists of twenty seven Unidades Federativas (Federative Units): twenty six estados (states) and the Distrito Federal (Federal District) as shown below (Estatística, 2012).

Table 4: Area (sq km^2) of the states in Brazil

			Area (sq km)
Acre	AC	Rio Branco	152,581.40
Alagoas	AL	Maceió	27,767.70
Amapá	AP	Macapá	142,814.60
Amazonas	AM	Manaus	1,570,745.70
Bahia	BA	Salvador	564,692.70
Ceará	CE	Fortaleza	148,825.60
Distrito Federal	DF	Brasília	5,822.10
Espírito Santo	ES	Vitória	46,077.50
Goiás	GO	Goiânia	340,086.70
Maranhão	MA	São Luís	331,983.30
Mato Grosso	MT	Cuiabá	3,357.90
Mato Grosso do Sul	MS	Campo Grande	357,125.00
Minas Gerais	MG	Belo Horizonte	586,528.30
Pará	PA	Belém	1,247,689.50

Paraíba	PB	João Pessoa	56,439.80
Paraná	PR	Curitiba	199,314.90
Pernambuco	PE	Recife	98,311.60
Piauí	PI	Teresina	251,529.20
Rio de Janeiro	RJ	Rio de Janeiro	43,696.10
Rio Grande do Norte	RN	Natal	52,796.80
Rio Grande do Sul	RS	Porto Alegre	281,748.50
Rondônia	RO	Porto Velho	237,576.20
Roraima	RR	Boa Vista	224,299.00
Santa Catarina	SC	Florianópolis	95,346.20
São Paulo	SP	São Paulo	248,209.40
Sergipe	SE	Aracaju	21,910.30
Tocantins	TO	Palmas	277,620.90

According to the U.N. FAO, 62.4% of Brazil is forested. As a country that was rich in natural resources, it seemed that Brazil was merely waiting for an economic awakening which came with the transition of a military dictatorship to a democratic society in 1980. The growth of the economy was accompanied by the migration of its citizens from rural to urban regions in search of employment. This resulted in dense populations for major cities.

Although Brazil's population density of 23.8 people per kilometer (UN Data, 2010) might not be as high compared to other smaller countries, the actual problem lies in the population density of major cities and not the country. According to a study by the UN Department of Economic and Social Affairs in 2007, coming in at number 4 at the highest urban agglomeration after Mumbai, and surpassing Delhi, Sao Paulo was occupied by 18.8 million people. In the same study, Rio de Jenairo came in 14th with 11.7 million people.

The population in Brazil is more concentrated on the coast, which is partly explained by the European colonization (1500s onward) that took place in those areas. In the North region, the country still has 7 unoccupied areas, mainly because of the presence of huge and dense forests, such as the Amazon. Population distribution can also be understood as a reflection of economic development. São Paulo, where the population density reaches 160 people per square kilometer, accounts for more than one third of the country's GDP. Among Brazilian regions, while the North is responsible for hosting only 7% of the country's population, the Southeast hosts 40%, with more than 22% of the population living in São Paulo, the largest state in the Southwest region. (Cherman & Akira, 2011)

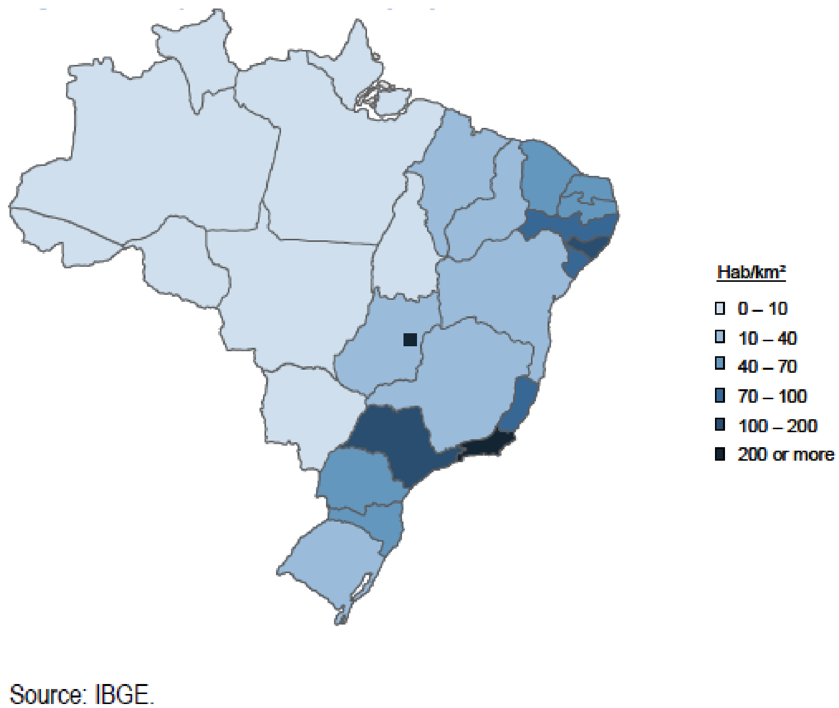
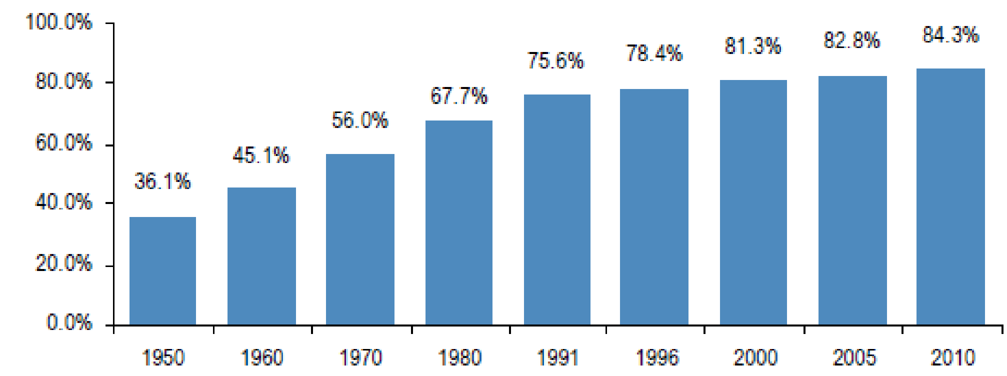


Figure 11: Population Density by State

Since 1950, the rate of regions urbanizing has been rising as a result of the economy and the population of people living in areas has more than doubled.A direct result of the population density is the appearance of informal housings or favelas. Favelas occupy a significant portion of urban land. Close to a third of São Paulo's 11 million people — in a metropolitan region of almost 20 million — live in slum-like conditions. There are some 1,600 favelas (private or public lands that began as squatter settlements), 1,100 "irregular" land subdivisions (developed without legally recognized land titles), and 1,900 cortiços (tenement houses, usually overcrowded and in precarious state of repair). (Xavier & Magalhaes, 2003)



Source: IBGE.

Figure 12: Urban Population as % of Total

2.4.1.2 Economy

Brazil has overcome a great deal of political difficulties resulting in economic turmoil. Gaining independence from Portugal in1822, Brazil became a constitutional monarchy. A military coup in 1889 established a republican government. However, women and the illiterate population were kept from voting during this time with the results of election polls predetermined. This was followed by a periods of dictatorship and military rule until Brazil again became a democratic state in 1985 (Gerring, Kingstone, Lange, & Sinha, 2011).

With the change in policy Brazil has seen a rapid economic growth to become the seventh biggest economy in the world Naturally rich in resources, most production is mainly for the domestic market. In terms of sectorial composition, the Brazilian economy is dominated by the service sector, which makes up more than half of the economy; followed by the manufacturing sector, at about 30 percent; processed food; agriculture; and natural resources. Major exports include transport equipment, iron ore, soybeans, footwear, coffee, auto motives bringing in a total value of US $199.7 billion (Polaski et al., 2009). Brazil currently has a GDP of US $2.088 trillion with one of the fastest growing economy in the world last year with a GDP growth rate of 7.5% (UN Data, 2010).

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Table 5: Macroeconomic Components of Brazilian GDP

Macroeconomic Components of Brazilian GDP
(Expenditure as Percentage of GDP)

Component	Percent
Private consumption	61
Government consumption	20
Investment consumption	16
Import demand	14
Export supply	17

In addition, the sectoral composition of the Brazilian economy is shown as follows:

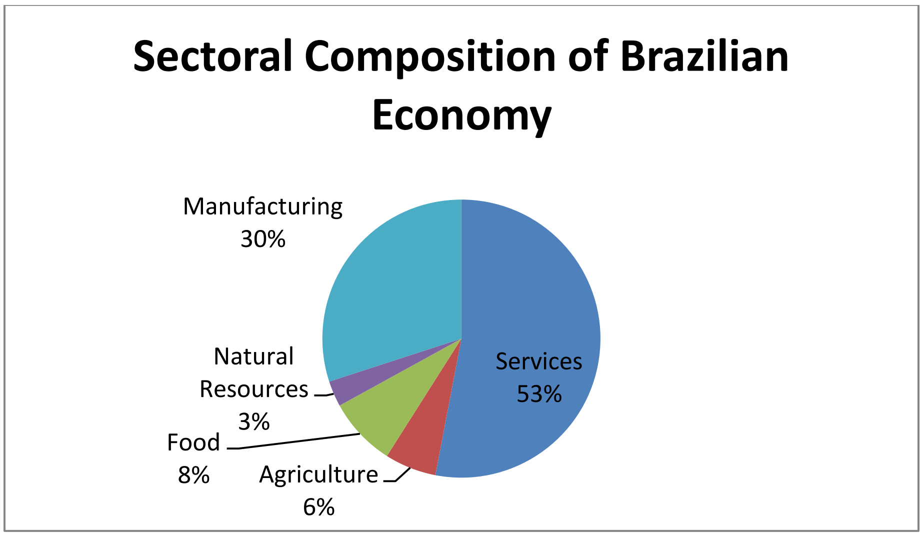

Figure 13 Sectoral Composition of Brazilian Economy

Because the Brazilian economy depends greatly on domestic consumerism and is also rich in natural resources, the economy continues to grow to be the seventh largest economy in the world. Although experts predict that this rate of growth will decrease, Brazil has a very stable economy.

Despite its strong economic performance, an important problem that should not be overlooked is the inequality in income distribution. In this category, Brazil ranks poorly when compared to other countries as one of the highest income inequalities in the world. One method to measure the income distribution is by the Gini coefficient- zero means that income is perfectly distributed and one for perfect inequality. In 2007, Brazil ranked 113th out of 123 countries. However, Brazil has shown great signs of improvement since the beginning of the 21st century as the income inequality declines sharply and rapidly. At the current rate of improvement, it would take 20 years for Brazil to be on par with highly developed countries. (Cherman & Akira, 2011)

2.4.1.3 Infrastructure

In terms of infrastructure for tourism, Brazil has remains underdeveloped with the quality of roads, ports and air transport ranked 106th, 127th , 89th of 133 countries respectively. Overall, Brazil's overall infrastructure ranked 74th which is even lower than the Latin American regional average. Overall investment-to-GDP ratio averaged 17% in the past 5 years compared to China's 44%, India's 38% and Russia's 24%. However, with scheduled projects to improve its infrastructure such as the 2014 World Cup, 2016 Summer Olympics, pre-salt oil reserves and government-backed Acceleration Program, there is optimism that Brazil is in the process of improving its infrastructure.

The Programa de Aceleração do Crescimento – PAC –is a federal government program launched in 2007,aiming to accelerate the country's economic growth through investments in infrastructure, such as housing ,transportation, utilities and sanitation. At the time of launching, the government forecast more than R$650billion in investments between 2007 and 2010. Regarding the origin of the money, the estimates were that 45% would come from state-owned companies, 40% from the private sector and 15% from the national budget.

Other projects that invest in the infrastructure of Brazil are the World Cup 2014 and Summer Olympic Games in 2016. The country plans to spend R$11.4 billion on transportation and R$5.7 billion on stadiums. Regarding the stadiums, none existing meets FIFA standards, meaning that they will either be built from scratch (Sao Paulo, for example) or undergo extensive renovations (Rio de Janeiro). Resources for stadiums are around US$2.7 billion. Brazil is aiming to invest an addition R$12.5 million for the Olympic Games. (Cherman & Akira, 2011)

2.4.1.4 Construction Sector Development

The increasing demand for housing is evident in the construction sector of the economy. In the first ten months of 2010, production of inputs for construction in the Brazil increased by 12.89% over the same period last year. In addition, the construction sector costs increasing from 3.56% of the industry to 7.52% in just one year (UK Trade and Investment, 2011)The construction industry can be divided into three segments: heavy, commercial and residential. Of the three, the residential housing segment is the largest in terms of share of GDP and employment (McKinsey Global Institute, 2009).

2.4.3 Building and Fire Code Policies

2.4.3.1 Uniformity in Codes

In Brazil building and fire codes differ by state. Although Brazil has a national fire standard, for example, it is not required to be applied everywhere uniformly, and detailed regulations vary from state to state. Because the codes are largely prescriptive, this regional division can be more catered towards the specific region's conditions. However, most of the 27 states follow the codes of the Federal District and Sao Paulo. This excludes several major states such as Rio de Janeiro, Minas Gerais and Rio Grande do Sul which follow their own codes.

The lack of uniformity in codes results in some states having more advanced codes than others and Sao Paulo is said to have the most advanced codes especially for steel structures. Although the fire codes of Sao Paulo is dominantly prescriptive, there is also the code of the Federal District which accepts an alternative solution as long as its safety can be proven. As a result of these different codes, there are a lot of unnecessary complications. For example, an building that has been approved in Sao Paulo may not be approved in Rio de Janeiro. (Braga, 2012)

2.4.3.2 Code Development

The Associação Brasileira de Normas Técnicas (ABNT) or Brazilian Standards Association develops and revises Technical Standards and Codes. It was established in 1940 and membership is open to anyone from students to organizations. The ABNT distinguishes that standards have a national status which is to be adhered by all engineers and architects. On the other hand, codes are mainly developed by municipalities and mention the standards. The Building Code encompasses fire protection aspects as well as fuel gas and plumbing codes. The proposal for the development of the codes and standards is open to the public. The ABNT then processes this proposal by the following means:

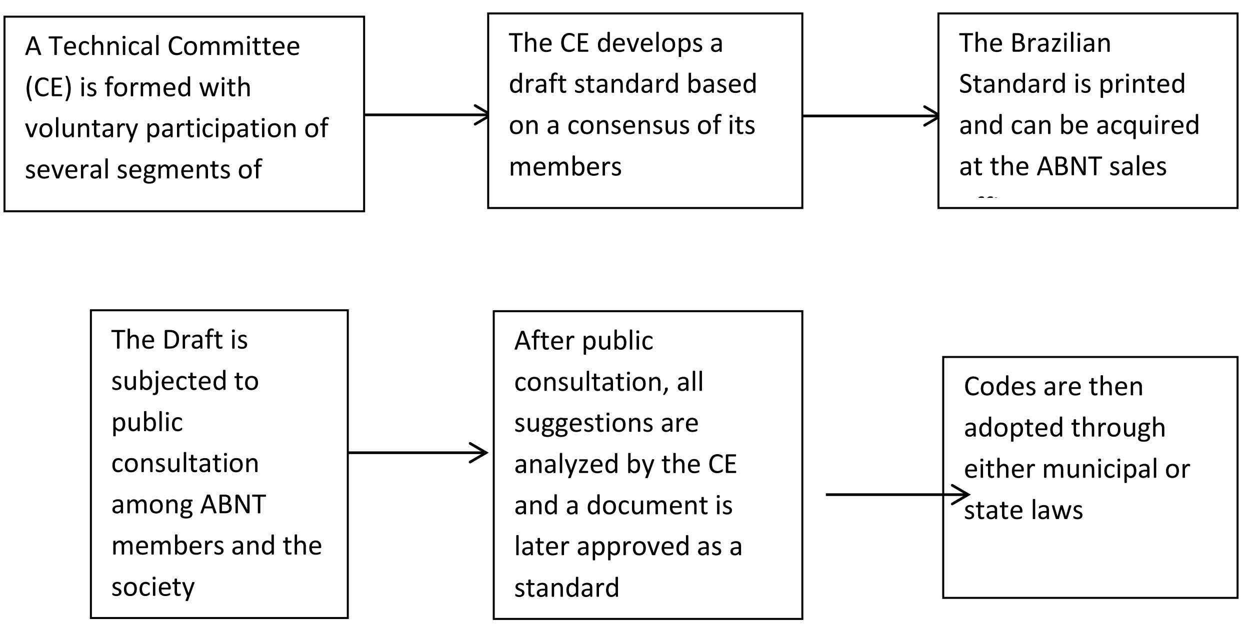

Figure 14 Process of the Development of Codes

The following organizations and individuals participate in the development of building codes and standards: the Building Department, public works/ministries, the Fire Department, professional associations, Professors/ Universities, manufacturers, testing labs, independent engineers/ architects/ technicians, insurance companies and builders and users (Técnicas, 2002).

2.4.3.3 Implementation of Codes

The fire departments of Brazil are state departments with each state having a paid fire department. The average of fire fighters per population in Brazil is around 1 for every 2,850 people. This number varies with state: in Brasilia, there is 1 firefighter for 500 people but in states like Maranhao, the ratio is 1 firefighter for 7,735 people (Braga, 2012).

However, the most important aspect of codes and regulations is the implementation of fire codes in buildings to ensure safety for its occupants. In order to ensure that codes are being followed, it is necessary that both the official from the Fire Department and the engineers of the project understand the codes. Brazil is certainly developing in terms of its fire knowledge with its research programs although there are still numerous fire accidents in which even basic fire suppressing units such as sprinklers were not installed.

This is evident in recent fires such as the fire of a research center in Sao Paulo, in which the entire collection of snakes, spiders and scorpions used to develop vaccines was destroyed by fire. The center was said to have no sprinkler or fire alarm system despite the flammable liquid it uses to preserve the species.

The favelas in Sao Paulo have no fire protection system in place. Favelas are not only made with highly flammable materials but due to the close proximity of the shacks, fire spreads with a quick rate (Claret, Baranoski, & Felicetti, 2011). These informal settlements, which reflect the severely disproportionate distribution of wealth, are one of the challenges Brazil faces as the country strives to establish itself as a major player in the world politics. One of the solutions to improve informal settlements is government funded housing which falls into the category of high rise buildings (Construção, 2010). Favelas today are usually closely associated with crimes and police have little or no control in most favelas.

2.4.4 Education and Market Capacity

2.4.4.1 Fire Protection Engineering Programs

In Sao Carlos School of Engineering, Professor Pignatta has created an undergraduate discipline that addresses fire safety issues. This program was created in 2010 and is the first of such undergraduate course in Latin America. The course is called "*Projects of structures in fire Situation"*. In addition, there have been similar courses in the graduate curriculum since 1999 (Paulo, 2012).

Progress in the advancement of fire knowledge is seen from the laboratories that have been set up in Brazil. In 1979, based on an agreement between the Technological Research Institute of Sao Paulo State (IPT) and National Institute of Standards and Technology (NIST) a laboratory was set up that allowed training of human resources and acquisition of apparatus for the testing laboratory. New opportunity for technical cooperation was also obtained, this time with Japan through Japan International Cooperation Agency (JICA) as Professor Makoto Tsujimoto was sent for a nine month training program. The first simulation of smoke movement was done in high rise buildings in Brazil at that time to better understand the performance of different types of staircases in high rise buildings in Brazil. The success here led to another cooperation proposed by the Japanese government led by the Building Research Institute (BRI). (Ono, 2005)

2.4.4.2 Current Situation of Fire Protection Engineers

Performance-based fire codes depend greatly on specialists to define the level of safety. However, fire safety is not a compulsory discipline in the undergraduate courses of architecture or engineering, so it is not properly discussed at this level. As a result, most of the building construction professions complete their education with little or no knowledge of the responsibility on ensuring fire safety by designing and construction of buildings. The research is not focused on this transition as well. Of the 26 research groups in fire related subjects distributed in 12 universities and 3 research centers, only 5 of the 26 focus on general matter of fire safety in buildings. (Ono, 2005)

Although Brazil has shown signs of development in the research of fire, there is still not enough emphasis placed on the development of performance-based codes or providing engineers with a scientific knowledge of fire. The fire department generally consists of civil engineers who are familiar with the structural aspect of the building but cannot predict smoke movement or egress flow. (Braga, 2012)

2.4.4.3 Market and Regulatory Needs for Education

The combination of a rapidly growing economy and the urgency to find a solution to informal settlements places an emphasis on the market's need for a performance-based system that can be cost-effective and improve safety. The financial factor is capable of playing a big role in the construction of high-rise buildings to improve the quality of the favelas and given the disastrous fire history of Brazil, performance-based codes can also improve the safety of high-rise buildings.

2.4.4. Summary

Brazil proves to be an interesting case study as it is unique in the aspect of having the most developed economy of the three countries reviewed, yet it lags behind in aspects of fire safety development. Although Brazil has shown significant economic growth and as a result, follows the urbanization trend, it can be observed that Brazil lags behind in the development of performance-based fire codes. One of the major challenges Brazil is tackling is the informal settlements which is a consequence of joint effects of continuous economic growth, rapid urbanization, and enlarged economic disparity between urban and rural areas. There is not certain way of knowing the number of fire incidents in favelas despite the frequency of fire occurrences in these regions. In addition to this, Brazil highlights the importance of having a regulatory structure that can smoothly implement changes and updates as well as the importance of enforcement. The fire codes that vary from state to state make system changes such as updating the method of data collection difficult.

Chapter 3: Assessment Methodology

3.1 Introduction

In the beginning stages of this project, significant time was spent researching on each of the three individual countries. Through this research period, important knowledge was gained on prescriptive and performance fire codes as well as unique characteristics of the three countries. This chapter looks at how the information obtained was assessed for each country to determine at what stage each country is in terms of transitioning to PB codes. Through the insights gained during the research process, the drivers for transitioning to PB fire codes were identified and a method was established to analyze and assess each country's potential to successfully transition to PB codes.

In order to compare the situation of the three countries studies, a scoring rubric was set up for each of the driving factors in urban environment, fire code policies and education capacity and market competence. However, since each of the driving factors was broad and general, smaller components having a direct relationship to the driving factor were identified. By breaking down each driving factor into smaller components each driving factor could be analyzed more thoroughly. For each of the components, a grading scale of 1 to 5 was set with 1 being the lowest score and 5 being the highest score. Given the diversity in factors between countries (e.g., population), it was difficult to establish quantitative targets for several of the variables in a manner that allowed for straightforward comparison. As such, it was decided to use qualitative descriptors only (e.g., little migration from rural to urban locations, highly prescriptive regulations, few fire protection engineers). Future research could perhaps result in specific ranges of values which can be used for comparison.

Also, while consideration was given to providing different weights for the individual factors and subcomponents, in the end, it was decided to assume all weights as equal for this first order analysis. Again, this is a function of data availability. Future such assessments could be refined based on development of a weighting factor based on relative contribution of each factor to the overall subject area. Since all weights were taken to be equal, a simple average score across each factor and component serves as the basis for comparison. The ranking system for each driving factor was established to provide a numerical value for grading.

3.2 Urbanization

3.2.1 Rubric Development Process

There are numerous factors that influence the urban environment of a country. People migrate to areas where economic activities take place seeking for economic opportunities. With this sudden influx of people resulting from migration, the area becomes crowded and there is an increase in demand for housing and transportation becomes. To meet for such demands within a crowded region, vertical growth is a common outcome that results. New pavements and transportation networks are delivered by the construction sector to provide accessibility within the region and housing demands. Consequently, the region becomes filled with high-rise and large complex buildings with newly paved roads and established means of transportation. It is within these high-rise and large complex buildings where need of PB codes becomes prominent. Along with the newly attained high standard of living from the economic development, a longing for improved safety is established in the minds of many. PB fire codes, with their flexibility and requirement of better understanding of risks and improved safety performance, have the potential to meet the safety demand issues in terms of building fire safety.

Through such understanding, the urbanization driving factor was divided in to sub-components of urban settings, economy, infrastructure and construction sector for the urbanization grading rubric. By assessing each country's standing in urban settings, economy, infrastructure and construction sector, it was thought that a good grasp of information on how much each country is in need of transitioning to and implementing PBD fire codes would be accomplished.

3.2.1 Urbanization Scoring Rubric

	S. Korea	**Poland**	**Brazil**
Urban Settings			
Economy			
Infrastructure			
Construction Sector Development			
Averaged Score			

A. Urban Settings: The rural population has been moving to urban or sub-urban areas of the country resulting in majority of the proportion of the total population inhibiting in urban areas and growth in area of cities. Rapid population growth often results in high population density in urban areas where old structures are destroyed and new complex and high-rise structures are erected, acclimatizing the utilization of PB codes. However, lack of careful urban planning and the existence of old establishments in the urban settings which could not go through a complete overhaul due to poor wealth distribution, could also cause fire hazards which may be existent in slum like areas where buildings are less fire proof or where buildings may be constructed in close proximity such that it may be hard for fire trucks to gain access for any rescue or suppression activity.

1. Little or no migration of population from rural to urban areas with the proportion of the rural population being majority of the total population. No particular fire hazard therefore resulting (from urbanization).

2. Some migration of population from rural to urban areas, but the disparity between rural and urban population is minute. However, migration seems to be resulting in fire hazards due to the informal settlements.
3. Migration to the urban areas is becoming a popular phenomenon and both the urban population and area are growing steadily. Increased urbanization is resulting in fire hazards associated with fast-growing urban settlements: formal and informal.
4. Migration to the urban areas has been ongoing for a while, resulting in large urban population and areas. Since the urbanization has been happening for some time, fire hazards are understood, and are largely related to densification and redevelopment.
5. Majority of the country and proportion of the total population are considered 'urban' and the urban areas are well established. Since environment is well-established, fire hazards are understood, and are largely related to densification and redevelopment.

B. <u>Economy</u>: A nation's economy is a measurement of the standard of living of the people in the nation. With economic development, the standard of living grows and the nation will start using the generated capital to invest in satiating the desires of people. As the people's desires become fulfilled, they will have the luxury to start turning their heads to safety issues. As a result, fire safety will also receive the public's attention and development in fire codes will occur naturally. As the economy improves, resources are available to support performance.

1. Very Poor standard of living with no significant economic development.
2. Poor standard of living, at least in some sectors (stratification exists), but seeing limited economic development.
3. Average standard of living, with some stratification, with economic development improving.
4. Good standard of living, less significant stratification, with very good economic development (but still some room for improvement).
5. Excellent standard of living across most sectors, with the nation's economy being established as a global financial engine and still surging for future growth.

C. <u>Infrastructure</u>: Physically well established and organized public infrastructure interconnects cities, allows cities to thrive, and is required to support the economic activities and social well-being of a nation. Good public infrastructure provides a solid foundation for a nation's economic and social development. Transition to PB codes difficult without good infrastructure.

1. Very Poor state of infrastructure development and capacity, with a major overhaul required to improve water supplies, information technology, and transport networks to support urbanization and economic growth.
2. Poor state of infrastructure development and capacity, with a lot of work required to improve water supplies, information technology, and transport networks to support urbanization and economic growth.

3. Average state of infrastructure development and capacity, with a lot of work required to improve water supplies, information technology, and transport networks to support urbanization and economic growth.
4. Good state of infrastructure development and capacity, with some work required to improve water supplies, information technology, and transport networks to maintain urbanization and economic growth.
5. Excellent state of infrastructure development and capacity, with well-established water supplies, information technology and transport networks fueling stable urban environments and economic growth.

D. <u>Construction Sector Development</u>: The construction sector undertakes activities of renovating, demolishing and erecting structures. The construction sector also requires keeping up with and implementing new technologies to accommodate modern architectural styles and materials. With modern architecture leaning towards high-rise and complex style structures, PB codes are becoming more and more feasible and in some cases necessary. In low stages of construction sector development, prescriptive codes may be most appropriate, as not many building changes or innovation is resulting. As urban environments grow and become mature, PB codes can help facilitate rapid development and unique buildings.

1. Very few new structures. A majority of the structures are old and have not gone through, or expect to go through, the process of demolition and rebuild, or renovation and expansion (low tech: low growth).
2. A small number of structures are newly built, some being high-rise or large complex structures, but many structures still old not having gone through the process of demolition and rebuild, or renovation and expansion.
3. A moderate number of the newly built high-rise or large complex structures has recently been seen, or are in planning, with numbers on par with the old buildings that have not gone through the process of demolition and rebuild, or renovation and expansion. Increasing complexity and innovation of buildings being seen.
4. A large number of the newly built high-rise or large complex structures has recently been seen, or are in planning, with numbers exceeding the old buildings that have not gone through the process of demolition and rebuild, or renovation and expansion. Increasing complexity and innovation of buildings is becoming prevalent.
5. A majority of the structures in the area are of newly built high-rise and large complex buildings. Increasing complexity and innovation of buildings is becoming prevalent.

3.3 Building and Fire Code Policies

Building and fire codes work together to dictate the safety level of a building. As a result of large numbers of disastrous fires over the centuries, building and fire codes have been established in most countries, and are recognized to be as significant contributors to fire safety of people and property. Building and fire codes can be nationally or locally developed and promulgated. National codes are typically adopted uniformly across an entire nation. Some advantages of a national code include national consistency and uniform implementation. However, this is not possible in some countries due to the form of government. In the USA, for example, building and fire codes are the responsibility of states, and the federal government has no role. In other countries, local or regional codes have the advantage of catering to the need of each locale. Because regions can be vastly different in terms of climate, propensity for specific natural hazards, urbanization and so forth, localized codes can sometimes be more to local needs (Meacham, 1998).

The nature of codes plays a significant role in the transition to performance-based codes. The case exhibited in the U.S. shows that the absence of a national code results in the decentralization of regulation power coupled with the rise of model codes developed by the private sector. This results in a number of complex issues which ultimately leads to a failure to transition to a completely performance-based regulatory system. (Meacham B. J., A Brief Overview of the Building Regulatory System in the United States, 2011)

3.3.1 Rubric Development Process

Because each country differs from one another in various was in terms of government, environment, geography, economy and social norms, there is no singularly correct way to develop building and fire codes. A method that works well in one country may prove to be disastrous in others. Therefore, countries develop their own codes as fit their needs. Some countries develop national codes for uniformity and to minimize confusion. However, other countries choose to develop codes by state, which results in a tailored and specific code for the region. However, with economic growth and the development of new cities, states that have different codes can sometimes result in obstructions, or at least challenges, for designers and architects. This proves to be a disadvantage for emerging cities with growing economies and as a result highlight the importance of uniformity. The specifications in prescriptive codes that aim to encompass every situation produce a large volume of codes that can easily create confusion. In addition, a simple code that is clear and concise greatly helps the engineer or building official and decreases the odds of confusion and possible legal issues. The content of building and fire codes can be improved as the knowledge of fire safety increases and the codes can be further developed. Lastly, code enforcement is determined to be a deciding factor when the fire history of a country is inspected. Some fires indicate the lack of basic fire requirements such as alarms and the extinguishers.

A country's fire code policies determine the approach that the country will take towards fires. As previously discussed, the factors that are selected to be the most significant are the uniformity in codes, development of the codes with respect to the increasing knowledge of fire safety and the level of which these codes are enforced.

3.3.2 Building and Fire Code Policies Grading Rubric

	S. Korea	Poland	Brazil
Uniformity in Codes			
Code Development			
Code Enforcement			
Average Score			

A. Uniformity in Codes: Depending on the country, building and fire codes can be national or can differ by state. An inspection of previous countries that transitioned from prescriptive to performance codes suggests that codes on a national level eases the transition, as only one set of documents needs to change. While it is recognized that not every country can implement national regulations, uniformity of regulations, and their implementation, is critical.

1. There is no singular code system. Implemented codes differ greatly from one state or jurisdiction to another, and there is no indication that this might change.
2. There is no singular code system. Implemented codes vary by state or jurisdiction; however, several states or jurisdictions follow a common set of codes, thus reducing, but not eliminating, variability across the country.
3. There is a singular code system, but not nationally mandated. A majority of states and territories implement the codes; however, there are numerous regional modifications.
4. There is a singular code system, but not nationally mandated. However, a majority of states and territories implement the codes with few modifications.
5. There is a national fire code which is uniformly implemented across the country.

B. Code Development: As the understanding fire safety factors such as the dynamics of fire and smoke movement increases, the codes can be developed in ways to simplify the previously written prescriptive codes into more flexible performance-based codes.

1. Codes are extremely prescriptive and complex, with few opportunities to allow variations. Regulatory infrastructure is not in place to support performance codes.
2. Code significantly prescriptive and complex, but opportunities exist for engineered (PB) alternatives. Regulatory infrastructure is not in place to support performance codes.
3. Codes are have a mix of prescriptive and performance. Engineered (PB) alternatives are allowed, but approval can be difficult. Regulatory infrastructure starting to be put into place to support performance codes and design.
4. Codes are have a mix of prescriptive and performance. Engineered (PB) alternatives are allowed and infrastructure is in place to support ready approval of PB designs. Regulatory infrastructure nearly ready for support of performance codes and design.
5. Codes are performance-based. Performance-based design readily accepted. Regulatory infrastructure well in place.

C. Code Enforcement: Regardless of how well-structured the codes are, a critical factor in fire safety performance is how well the codes are enforced. This category considers fire history, statistics and published reports with respect to fire occurrences and how well codes are enforced.

1. Codes are not followed and no inspection is required.
2. Codes are followed only in high profile buildings and inspection is spotty.
3. Codes are generally followed, inspection is required, but not for all buildings.
4. Codes are followed and building is expected regularly, although perhaps not yearly.
5. Codes are strictly followed, regular inspection, often annual, conducted.

3.4 Education Capacity and Market Competence

3.4.1 Rubric Development Process

While education was identified as one of the three general driving factors behind a nation's transition to PB building and fire codes, there are a number of dynamics which contribute to education as a driving factor. The occupation of fire protection engineer (FPE) must be outlined and governed by a nationally recognized authority which certifies individuals who are capable of performing the tasks of a FPE. The level of experience and training with performance-based design (PBD), which the country's FPEs possess, must be evaluated and subsequently increased through continuing education. There must be established, appropriate secondary-education programs and research infrastructure, working hand and hand, which teach and advance the fundamentals of PBD within the country's borders. Finally, there is a direct relationship between the transition to a PB system and the market and regulatory demands for properly-educated FPEs: if there are no qualified FPEs, it is difficult to undertake PB designs, and if there are PB designs to review, there needs to be qualified FPEs to evaluate and approve PB fire safety designs.

Therefore the Educational Capacity and Market Competence comparative analysis grading system was divided into the following categories: Fire Protection Engineering Programs, Fire Protection Engineering Research, Current Experience of Fire Protection Engineer's with Performance-Based Design, Consistency of Training Level throughout the Country, Market Need for FPE Education and Regulatory Need for FPE Education.

3.4.2 Education and Market Competence Grading Rubric

	S. Korea	Poland	Brazil
FPE programs			
FPE research			
Current experience of FPE's with PBD			
Consistency of training level throughout country			
Market need for FPE Education			
Regulatory need for FPE Education			
Average Score			

A. Fire Protection Engineering Programs: The current number of fire protection engineering programs offered and their capacity to educate fire protection engineers in the area of performance-based design (PBD) in the country in question.

1. No fire protection engineering (FPE) programs.
2. Small number of fire protection engineering (FPE) programs.
3. Moderate number of fire protection engineering (FPE) programs.
4. Significant number of fire protection engineering (FPE) programs.
5. Extensive number of fire protection engineering (FPE) programs.

B. Fire Protection Engineering Research: FPE education must be supplemented by research. This criterion evaluates the current level of research in support of fire protection engineering, including but not limited to performance-based design (PBD).

1. No discernible research in direct support of fire protection engineering.
2. Small amount of research in direct support of fire protection engineering.
3. Moderate amount of research in direct support of fire protection engineering.
4. Significant amount of research in direct support of fire protection engineering.
5. Extensive amount of research in direct support of fire protection engineering.

C. Current Experience of Fire Protection Engineers with PBD: Extensive education and experience is necessary to not only prepare, but also evaluate, PBD reports. This criterion evaluates the level of experience fire protection engineers (FPEs) have with PBD.

1. No discernible experience with performance-based design.
2. Limited experience with performance-based design.
3. Moderate experience with performance-based design.
4. Significant experience with performance-based design.
5. Extensive experience with performance-based design.

D. Consistency of Training Level throughout Country: Regions with the highest concentration of development, in most countries, have more experience developing and evaluating PBD than regions with little to no development. In order to successfully implement a national-based PB code, a consistent level of cross-sector training throughout the nation is crucial. This criterion evaluates the consistency of the cross-sector (e.g., architects, engineers, technicians, authorities) training level for PBD throughout the country in question.

1. No consistency in level of regional training for PBD.
2. Little consistency in level of regional training for PBD.
3. Moderate consistency level of regional training for PBD.
4. Significant consistency level of regional training for PBD.
5. Extensive consistency in level of regional training for PBD.

E. Market Demand for Fire Protection Engineers (FPEs): As the construction industry of a country is stimulated by economic growth and the number of "cutting-edge" and complex construction projects increases, the number of PBDs being conducted grows. Because of the increased number of PBD being performed, there is a sharp jump in the demand for competent fire protection engineers (FPEs) to conduct the necessary PBDs. The national market need for educated fire protection engineers will in turn promote the development of the country's educational capacity for fire protection engineering. This criterion evaluates the market need for educated fire protection engineers (FPEs) in the country in question. This is closely related to the need for FPE education programs.

1. No market demand for fire protection engineers (FPEs).
2. Limited market demand for fire protection engineers (FPEs).
3. Moderate market demand for fire protection engineers (FPEs).
4. Significant market demand for fire protection engineers (FPEs).
5. Extensive market demand for fire protection engineers (FPEs).

F. Regulatory Need for Fire Protection Engineers (FPEs): As the number of "cutting-edge" and complex construction projects increases and the number of PBDs grow, there is a sharp jump in the demand for competent fire protection engineers (FPEs) to evaluate and subsequently approve the PBDs. The national regulatory need for educated FPEs will in turn promote the development of the country's educational capacity for fire protection engineering. This criterion evaluates the regulatory need for educated FPEs to support PB regulation.

1. No regulatory demand for fire protection engineers (FPEs).
2. Limited regulatory demand for fire protection engineers (FPEs).
3. Moderate regulatory demand for fire protection engineers (FPEs).
4. Significant regulatory demand for fire protection engineers (FPEs).
5. Extensive regulatory demand for fire protection engineers (FPEs).

Chapter 4: Results and Analysis

4.1 Introduction

The above rubric was applied to each country considered: Korea, Poland and Brazil. A composite score for each factor was determined, by country, as summarized below. The scores for each country are then compared. As noted above, the scores were determined subjectively by the group based on the research conducted on each country.

4.2 Urbanization Results

As noted above, the Urbanization factor consists of Urban Setting, Economy, Infrastructure and Construction Sector Development.

4.2.1 Urban Setting Scores

4.2.1.1 Korea

Urban Settings Score: 4.5
Korea is assigned a score of 4.5 for the Urban Settings category. This is due to the high percentage of the population living in cities and density of buildings. Due to the urban settings, it seems that Korea's transition to PBD codes is inevitable. More than 80% of the total population in Korea is considered to inhabit in urban areas. However, although highly urbanized, because of the relative small land area and the high population density growth of these urban areas has highlighted problems that could occur in terms of fire safety when structures are built too closely. Because some structures are located too close to one another and also due to the narrow roads, it is hard for fire trucks to access some of these structures. Despite more than the majority of the total population are already considered urban population, migration of the rural population moving into urban areas is still the popular trend taking place and this will cause for demolition of old buildings for buttressing even more high-rise buildings throughout the urban areas.

4.2.1.2 Poland

Urban Settings Score: 3.5
Given the trend to urbanization, and the density of population as detailed above, Poland was assigned an Urban Setting score of 3.5. Poland is a country with an ever-evolving urban climate. The country's urban areas have made great progress since escaping from under cloak of Soviet rule but there are still areas which need improvement. Acceptance to the European Union will continue to drive urbanization in the years to follow. Hopefully, future foreign investment will stimulate development in urban zones, as they attempt to catch up to the growth of suburban zones. A national Performance-Based Fire Safety code would allow the construction of "cutting edge" and "prestigious" structures which will attract the foreign investment necessary to complete the urban transformation of Poland's urban epicenters.

4.2.1.3 Brazil

Urban Settings Score: 3

With respect to urban setting, Brazil is assigned a score of 3. The major cities are able to boast of the high rise buildings that display its sophisticated architecture like the Rio Sul Center or Edicio Santos Dumont with numerous projects currently under construction. However, the challenge of developing remaining areas such as the favelas although addressed is not quite answered. For this reason, Brazil is rated as a 3.

4.2.1.4 Urban Setting Scores Comparison

	S. Korea	Poland	Brazil
Urban Settings	4.5	3.5	3

Urban settings will differ from country to country. This is inevitable as all countries have differing geographical features. Because of this certain urban settlement patterns may be more suitable to different countries. Without urban settlements, the need for high rise and complex structures is minimal at best. One common characteristic of urban setting is the high population density in the urban areas. To accommodate for such features, vertical growth and large complex buildings are encouraged. It is these high-rise and large complex buildings where the positive benefits of the PBD could be reaped at full potential. Without such structures, the need for PBD is minimized and the flexible features of PBD cannot be fully utilized. From the three countries reviewed, all possess different and unique geographical features.

Table 6: Various characteristics of Korea, Poland and Brazil

	S. Korea	Poland	Brazil
Land Area (sq km)	100,032	304,510	8,456,510
Total Population	49.8 m	38.2 m	194.9 m
Urban Population	81.7%	87.0%	61.0%

Brazil and Poland are large in land area compared to Korea. As a result, it makes sense that Korea has higher proportion of the total population classified as urban population and higher population density then both Brazil and Poland.

However, for all three countries, a common trend of the rural population migrating to urbanized cities seeking for better economic opportunities was observed. Korea, although considered highly urbanized, was given a score of 4.5 because of the fire hazards presented as a result of the high population density and limited area. Brazil was given the lowest score of 3 out of the three countries due to areas of urbanized cities consisting large slum areas highlighting the disparity between the rich and the poor. The slum areas are a great concern of fire hazards and require further development. Poland was given a score of 3.5. The country’s urban areas have made great progress since escaping from under cloak of Soviet but there are still areas which need improvement. In terms of population growth, all three countries are entering stage five of the demographic transition model which indicates population decline marked by birthrates lower than the death rate. Population decline could help alleviate the high population density problems in each of the countries.

4.2.2 Economy

4.2.2.1 Korea

Economy Score: 5
Korea is assigned a score of 5 for the Economy category. Not only has Korea seen a tremendous economic growth in the past couple of decades but the newly reached heights have set Korea as one of the financial muscle power in the global economy. As mentioned in Chapter 2, the economic ascendance can be a measure of the growing urbanization. A positive trend in Korea is that building owners and occupants are not only looking to gain economical reaps but also looking into fire safety as well.

4.2.2.2 Poland

Economy Score: 4
For the reasons stated above, Poland is assigned an economic score of 4. Similar to the urbanization climate, the economy of Poland is constantly evolving while holding great potential in the years to come. Since gaining independence in 1989, Poland's economy has experienced gradual growth with limited setbacks. Poland's economy was able to weather the international economic disaster of 2008 with little to no apparent disruption to development. The most valuable economic asset of Poland is the country's landmass. Not only is the geographic location of the country crucial in trade throughout Europe, but the multitude of natural and renewable resources located within Poland's borders. The geographic location and resources of Poland will continue to attract escalating foreign investment. A national PB code system will only improve the attractiveness of Poland as an investment in the years to come as global companies attempt to increase their presence in the country of great stability and potential.

4.2.2.3 Brazil

Economy Score: 5
In spite of the global recession, Brazil was one of the few countries that still managed to grow. Because the Brazilian economy depends greatly on domestic consumerism and is also rich in natural resources, the economy continues to grow to be the seventh largest economy in the world. Although experts predict that this rate of growth will decrease, Brazil has a very stable economy. For these reasons, Brazil is assigned an economic score of 5.

4.2.2.4 Economy Scores Comparison

	S. Korea	Poland	Brazil
Economy	5	4	5

Urbanization is a measurement of economic development and economic development is a measure of the people's standard of living. Economic development has a great influence in terms of fire safety. Often times where the standard of living is poor, building owners or occupants will only look for financial benefits and use the building space to maximize profits not looking at what fire hazards might be presented by such means of building use. As the longing for higher standards of living is achieved through economic development, people have the luxury to turn to safety issues. Such shift in focus leads to importance being placed in safety issues and leads to improvements in fire codes. It is only then a country will even think of implementing PB codes as a means to improve upon the existing fire codes.

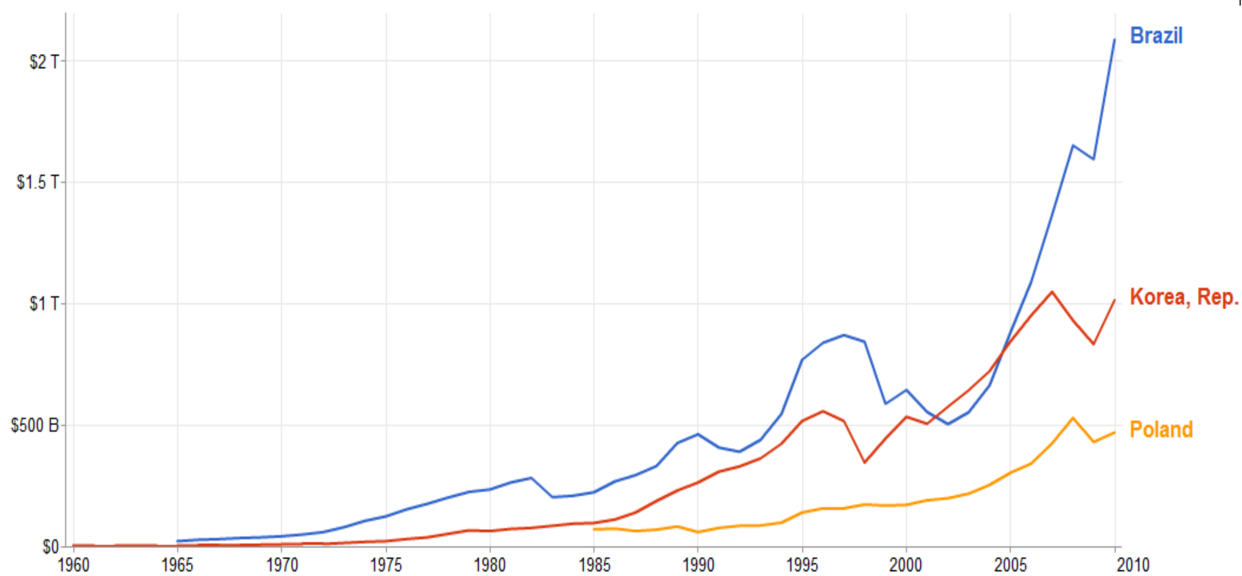

Figure 14: GDP growth rate comparison of Korea, Poland and Brazil

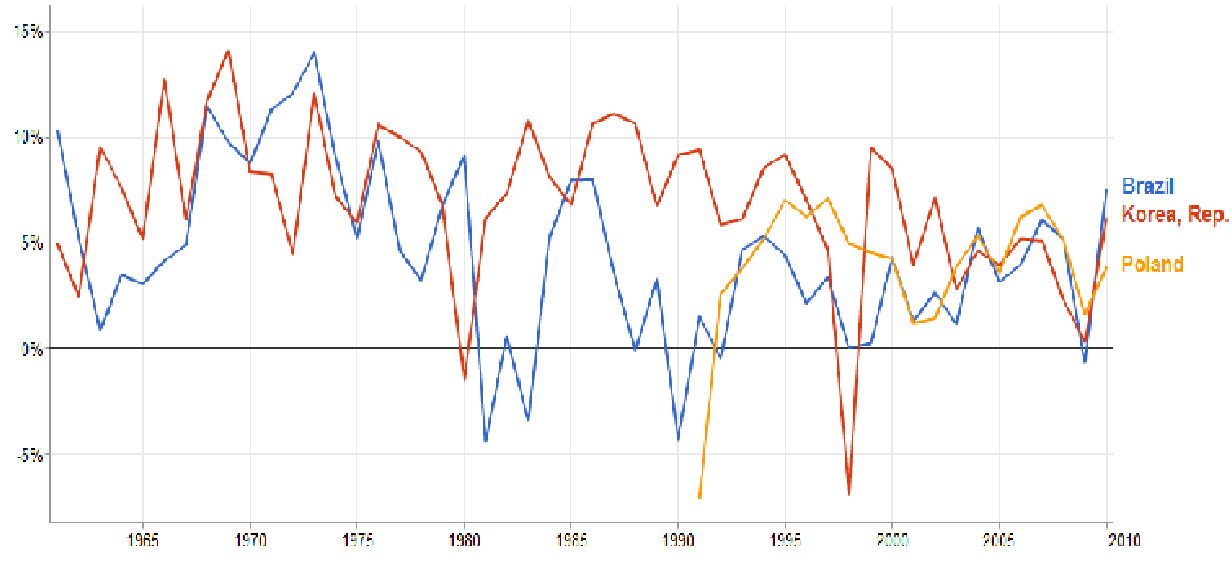

Figure 15: GDP Comparison of Korea, Poland and Brazil

Graphs above indicate that all three countries have seen their economies grow significantly over the last couple of decades. The graph indicates a positive trend in terms of GDP growth and seems likely that each country will see their economies grow larger in the future as well. Although there may be disparities between the rich and the poor the overall standard of living has improved greatly for the people of these nations. As a result, both Brazil and Korea was given a score of 5 and Poland was given a grade of 4. Poland, although having gone through rapid economic development, still has the potential for further development through their natural resources and foreign investment.

4.2.3 Infrastructure

4.2.3.1 Korea

Infrastructure Score: 5

Korea is assigned a score of 5 for the Infrastructure category. It has been proven time and time again through hosting mega-scale global sporting events that Korea can successfully host any and all events due to its impressive infrastructure. Korea has a great water supplies, transportation system and roads that make all cities highly accessible and well-connected. Bids to host these sporting events would have ended up in failure was it not for Korea's well established infrastructure.

4.2.3.2 Poland

Infrastructure Score: 2.5

Because of the reasons listed above, Poland received an Infrastructure score of 2.5. The current condition of Poland's infrastructure is completely unacceptable for a country with great aspirations and potential. Poland's geographic location has great importance of the sustainment of the country's promising development and without proper infrastructure, the true value will not be reached. As mentioned, steps have been made in the right direction in terms of Poland's infrastructure, but there is a still great stride which must be made. A national PB code system could provide architects with the flexibility necessary to design and construct structures which would attract large-scale sporting events such as the Olympics.

4.2.3.3 Brazil

Infrastructure Score: 3

Brazil has been criticized for not investing heavily enough in its infrastructure. Overall investment-to-GDP ratio averaged 17% in the past 5 years compared to China's 44%, India's 38% and Russia's 24%. However, with scheduled projects to improve its infrastructure such as the 2014 World Cup, 2016 Summer Olympics, pre-salt oil reserves and government-backed Acceleration Program, there is optimism that Brazil is in the process of improving its infrastructure. As a result, Brazil is assigned a score of 3 for its infrastructure.

4.2.3.4 Infrastructure Scores Comparison

A solid infrastructure is required to host mega-scale global scale sporting events. Through a well-established infrastructure including transportation networks and water supplies the whole country becomes inter-connected and accessible. In terms of mega-scale global scale sporting events, such infrastructural features are necessities to allow for guests to move from one site to the other. Such events also require large complex sporting facilities and housing buildings which could also require for need of PBD fire codes.

	S. Korea	Poland	Brazil
Infrastructure	5	2.5	3

All three countries have or will have the experience to host mega scale global sporting events. The prestige to hold such events requires a country to have a solid infrastructure. Korea's development earned it a score of 5 as the developing Brazil was graded a 3. Poland was given a low score of 2.5 due to its poor road conditions.

4.2.4 Construction Sector Development

4.2.4.1 Korea

Construction Sector Development Score: 5

Korea is assigned a score of 5 for the Construction Sector Development category. With construction technology research encouraged and plans to build whole new cities such as Songdo City, to allure foreign investments, Korea will keep growing vertically and the demolition of old structures will continue. Plans are already in place for numerous high rise buildings, such as the Busan Lotte World (will be 1674 feet), to get the construction underway. Korea definitely has the technology and economy to build complex buildings in which prescriptive codes may not be sufficient to provide appropriate level fire protection required.

4.2.4.2 Poland

Construction Sector Development Score: 4

Based on the reasons listed above, the country of Poland is assigned a Construction Sector Development score of 4. The construction industry in Poland has received large international building investments since joining the European Union in 2004. These "cutting-edge" buildings require a very flexible design approach. The current prescriptive codes are "not flexible and archaic in its structure." In addition the current Polish building codes are extremely ambiguous and contested. Performance-Based fire protection codes would provide architects the flexibility necessary to build the structures which the foreign investors desire thus further stimulating the construction sector. All the parts are in place for a flourishing construction industry in Poland. However the building and fire codes are restricting the growth.

4.2.4.3 Brazil

Construction Sector Development Score: 4

Brazil's thriving construction industry has encouraged further research into the consequences of fire. As a result, there is extensive research of heat on steel structure. Knowledge of the behavior of fire is a necessity for the transition to performance-based design. As a result, Brazil is assigned a score of 4 for the Construction Sector Development category.

4.2.4.4 Construction Sector Development Scores Comparison

The construction sector needs to develop in order to accommodate and implement new technologies to construct high-rise and large scale complex buildings. Often time great demand for housing in densely populated urban cities is the catalyst for the construction sector development. Also, demolition of the old traditional buildings for more aesthetically pleasing modern architectural structures occur providing further development to the construction sector.

	S. Korea	Poland	Brazil
Construction Sector Development	5	4	4

All countries had high ratings for construction sector development. This was largely in part due to the housing demand with a rapidly growing urban population. All countries have adopted modernized western style architecture and the process of destroy and rebuild has been occurring throughout each nation. Also, numerous high-rise and complex construction projects are an indicator of development in construction technology backed by strong economies. Further, all countries are encouraging research in construction technology to improve upon their already impressive construction sector.

4.2.5 Urbanization Scores

	S. Korea	Poland	Brazil
Urban Settings	4.5	3.5	3
Economy	5	4	5
Infrastructure	5	2.5	3
Construction Sector Development	5	4	4
Average Score	**4.875**	**3.5**	**3.75**

4.2.6 Urbanization Scores Analysis

It has been a common notion by many building designers that the prescriptive fire codes can be rigid and have limitations when it comes to designing these new complex buildings. A transition to performance based design fire codes has been the global norm as it provides flexibility while minimum fire safety levels can be sufficiently met at the same time. Therefore, urbanization is considered to be a major factor in countries turning to performance based design codes.

Economic development and urbanization go hand in hand. Development of one factor inevitably leads to development in the other factor. As this relationship stands true, it is not an understatement that urbanization is a measurement of economic development. Infrastructural development is essential for urbanization, industrialization, export promotion, equitable income distribution and economic growth to take place. As a result, it is common to see the construction sector growing at the same time economic development takes place. Urban population growth is a key factor contributing to the vertical growth in many metropolitan cities. As people migrate to cities to find better economic opportunities, construction of large complex and high-rise buildings occurs naturally to accommodate for the rapid population growth. Already, as of 2011, half of the global population resides in urbanized regions and this number is expected to reach 61.8% by 2050 according to the UN Habitat's report of *Urban Trends: Urbanization and Economic Growth*. To meet the demands, along with the advancements and innovations in construction technology of recent times, there has been an exponential growth in high-rise and complex buildings.

The final average urbanization scores show that Korea is the most urbanized out of the three countries, followed by Brazil and then Poland.

- Korea would have scored a perfect 5 if it was not for the fire hazards presented due to its urban settings. Although it seems inevitable for buildings in Korea to be built in close proximity, meticulous urban planning could alleviate such problems to mitigate the fire hazard issues.

- Brazil needs to improve its urban settings as there are slums referred to 'favelas' in the urban settlements. These favelas sometimes occupy large chunks of the urban settlement areas and are a potential risk for fire hazards.

- Poland has seen great urban development occur since gaining its independence in 1989. Urbanization is still in the process and this study has revealed many positives that will result in further urbanization occurring in Poland. Also Poland's infrastructure, which requires a lot of work, will improve as the country grows economically and preparations are being made to successfully host the European Championship in June 2012.

A detailed analysis of all three countries has revealed that urbanization drives the need for buildings, which in most cases are delivered through high-rise and complex buildings to subsidize for the limited land from rapid population growth. All such new construction projects drive the construction sector to grow which also directly affects the country's economy and infrastructure. Korea, Poland and Brazil have all seen experienced such phenomena. The high-rise and complex buildings is a key driving factor in transitioning to performance based fire codes which can provide flexibility and the creative freedom in terms of design which prescriptive based fire codes cannot offer.

4.3 Fire Code Policies Results

4.3.1 Uniformity in Codes

4.3.1.1 Korea

Uniformity in Codes Score: 3

Korea is assigned a score of 3 in the Uniformity in Codes category. Although one uniform national fire code exists, the separation of the fire code from the building code is a cause of concern to many due to many grey areas between them. Such gaps need to be closed and if the Ministry of Construction and Transportation and National Emergency Management Agency refuse to combine the two set of codes, they should at least work close in tandem to unify the differences in the codes so that building designers are not confused anymore.

4.3.1.2 Poland

Uniformity of Codes Score: 4

For the reasons states above, the country of Poland received a Uniformity of Codes score of 4. Between the Building Regulations Act and the Fire Safety Act, Poland has a well -established national-based administrative structure for fire safety regulations which promotes a country wide uniformity of codes. However many professionals in the country find the actual language of the codes very ambiguous and controversial. Therefore Poland is an excellent candidate for a PB fire protection regulation system. Not only would the transition from prescriptive to performance-based codes alter very little in terms of the administrative structure, the performance-based codes would cure many of the code issues which plague the country of Poland.

4.3.1.3 Brazil

Uniformity of Codes Score: 2

When transitioning to performance-based design, the implementation of these codes is easier as a result of a national fire code as exhibited by Australia. In addition, a national code seems to be more advantageous for Brazil for a smoother transition to performance-based design as well an easier approval process for a building across the country. There was even an effort to build a national code in 2006 which unfortunately did not produce results. Brazil is therefore assigned a score of 2 for its code uniformity.

4.3.1.4 Uniformity in Codes Scores Comparison

	S. Korea	Poland	Brazil
Uniformity in Codes	3	4	2

A pressing issue in Korea is not a code that differs state-wise but the separation of the building code and fire code. This is of significance as it results in unnecessary confusion about the codes and proves to be one of the challenges to face to transition to performance-based design. However, although Poland has not been involved in performance-based-design, it follows the EU structural design code (Eurocodes) as every member does. Lastly, Brazil has shown the disadvantages of not having a non-uniform apartment.

4.3.2 Code Development

4.3.2.1 Korea

Code Development Score: 4

Korea is assigned a score of 4 for the Code Development category. During the post Korean War and up till today, convenience and capital became the number one essentials of life with the economic boom and the new found affluence. Consequently, safety became a forgotten issue in the minds of many Koreans. As times changed so did the fire safety circumstances but only the fundamentals on which the Fire Services Act was established remained intact. The codes stayed untouched throughout the years only for the necessary ones to be modified from a result of a fire disaster. However, Korea's implementation of PBD codes is an indictment that fire safety may be becoming a prominent issue.

4.3.2.2 Poland

Code Development Score: 3.5

Because of reasons stated above, the country of Poland received a Code Development score of 3.5. Between the fire safety waiver clause and the implementation of the Performance-Based Eurocodes, Poland well positioned for a transition to a full scale Performance-Based fire safety code system. In the years to come, the development of Polish fire codes will only be limited by the education and experience of the country's fire protection codes because without sufficient training performance-based fire safety codes are completely ineffective.

4.3.2.3 Brazil

Code Development Score: 3

The following organizations and individuals participate in the development of building codes and standards: the Building Department, public works/ministries, the Fire Department, professional associations, Professors/Universities, manufacturers, testing labs, independent engineers/architects/technicians, insurance companies and builders and users. However, the codes remain largely prescriptive and complex and do not implement the use of modern technology that can greatly simplify the specifications of the codes. Brazil is assigned a score of 3 for the code development category.

4.3.2.4 Code Development Scores Comparison

	S. Korea	Poland	Brazil
Code Development	4	3.5	3

An issue that is almost as pressing is how the codes are developed. Brazil faces a challenge familiar to the US of how code development is not as regulated as it should be. As a result, fire codes are not as developed as they should be for a country of Brazil's caliber. On the other hand, Poland's transition to performance-based design is coming along smoothly to with the EU codes as a reference. The codes of Korea seem to lack some updates but this does not seem to affect the transition to performance based design.

4.3.3 Implementation of Codes (how well codes are actually followed)

4.3.3.1 Korea

Code Enforcement: 3.5

Korea is assigned a score of 3.5 for the Implementation of Codes category. Although all buildings go through the process of attaining building permits, fire marshals don't have the authority to make the final decision in terms of approving the fire safety design of the building. Fire marshals should be given more authority to directly approve or reject a fire safety design plan instead of only having the authority to voice opinions to the government officials. Also, an analysis of the newly established PBD codes indicate that it is still in the nascent stages and loopholes exist. The detailed discussion of Korean PBD codes is included in Appendix A.4.

4.3.3.2 Poland

Codes Enforcement Score: 2

For the reasons listed above, the country of Poland received an Implementation of codes score of 2. Poland's fire protection engineers' lack of experience and inconsistency of training with Performance-Based design has led to a sub-par level of fire safety reports and their subsequent approval. Further development of Polish fire safety regulations cannot occur until the country's fire protection engineers can master the implementation of the current codes.

4.3.3.3 Brazil

Code Enforcement: 2

Another significant factor in the urbanization of favelas is the powerful rural land-holding interests fearing loss to squatters on their properties. Because of the value of land in Sao Paulo, urbanization can be viewed as threat to powerful market players. More importantly, this leads to corruption in the regulatory system. This presents a huge problem in implementing performance-based design as there is already much debate in how to determine the safety levels in a performance-based design building without the added complication of corruption. Brazil is therefore assigned a score of 2 for code enforcement.

4.3.3.3 Implementation of Codes Scores Comparison

	S. Korea	Poland	Brazil
Implementation	3.5	2	2

Implementation of these codes is of extreme importance because this is the practical use of the codes. Korea had an issue of that the official who were inspecting the building the white in that theatre anywhere. Poland, on the other hand, presents the problem that the officials may not be quality. Brazil is assigned a score of 2 because the an inspection of the fires in Brazil proved that buildings lacked the basic fire safety requirements and the result concluded was that code enforcement was poor.

4.3.4 Fire Code Policies Scores

	S. Korea	Poland	Brazil
Uniformity in Codes	3	4	2
Code Development	4	3.5	3
Code Enforcement	3.5	2	2
Avg Score	**3.5**	**3.17**	**2.83**

4.3.5 Fire Code Policy Scores Analysis

Fire code policies determine the content of fire codes. In developing countries, due to urbanization and population densification, the number of high rise buildings increases dramatically. Due to its altitude and limited number of exits, escape routes are limited and the difficulty to extinguish fire in high rise buildings as a result of the accessibility is high. The history of fires in high rise buildings has resulted in the high death tolls and damage money. This results in an increasing emphasis on the importance of fire codes. With regions urbanizing, the number of high rise buildings increases and as a result, the importance of fire codes increase. To meet with the demands of a high rise building that is both safe and economical, performance-based codes have been an option that economically growing countries such as Australia have chosen (Beck).

The final average of fire code policy scores show that Korea leads the two countries with a score of 3.5 with Poland closely follows with 3.17. Brazil, despite its booming economy scored least with a score of 2.83.

- The confusion caused by the language in the Building Codes and the Fire codes in Korea is highlighted as the area that is affecting the uniformity of codes in Korea. This affects the progression to performance-based codes.
- In terms of fire codes, Poland is transitioning smoothly to performance-based codes with the help of the Eurocodes. Poland has proven to be capable of making changes to their codes to follow the structure of the Eurocodes. The only area where Poland can improve on is enforcing these codes.
- The analysis of Brazil shows that the country has great room for improvement for their fire codes. Because fire codes are different by state, change in codes is hard to implement. This result in a poor code development as these codes is not modified despite the progress in knowledge of fire safety. Lastly, the enforcement of the codes in Brazil is poor.

The assessment of the three countries reveals that despite economic growth and urbanization, the fire code policy is an extremely significant factor in the transition to performance-based codes. High-rise and complex buildings require a fire system that will ensure that safety of its occupants.

However, the presence of high-rise buildings does not usually guarantee a good system of fire codes. Because the fire codes that ensure safety do not progress along with the economy and urbanization, it is important to categorize and analyze them separately. In addition, as performance-based codes is economical, flexible and safe, the countries are judged on how far each country has progressed to the transition to performance-based fire codes.

4.4 Education and Market Competence Results

4.4.1 Fire Protection Engineering Programs

4.4.1.1 Korea

Fire Protection Engineering Education Score: 2
Korea is assigned a score of 2 for the Fire Protection Engineering Education category. It is impressive that there are about 70 departments within universities or community colleges that offer fire safety courses. Despite the great number of fire related departments, none offer the courses related to fire dynamics. When it comes to PBD, knowledge of fire dynamics is essential. It is important that Korea establishes a fire protection engineering program which includes the core class of fire dynamics to keep producing graduates with the proper knowledge to professionally perform PBD.

4.4.1.2 Poland

Fire Protection Engineering Education Score: 4
For the reasons listed above, the country of Poland received a Fire Protection Engineering Education score of 4. The presence of the Main School of Fire Service is a crucial asset to the development of Performance-Based fire safety codes in Poland because of its dedication to the education of fire protection engineers. While the curriculum of The Main School of Fire Services does not allow students to study Performance-Based Design as an entire system, the school educates students in some elements of Performance-Based Design. The country of Poland is steps ahead of most countries in terms of the education of Fire Protection Engineers but a full adoption of Performance-Based Design by the Main School of Fire Services would drastically improve the atmosphere of fire protection in the country.

4.4.1.3 Brazil

Fire Protection Engineering Education Score: 2.5
While Brazil has a moderate research being performed, the small amount of fire safety educational programs results in Brazil being assigned a score of 2.5.

4.4.1.4 Analysis of Scores and Ranking for Fire Protection Engineering Programs

	S. Korea	Poland	Brazil
FPE programs	1	4	2
FPE research	3	4	3
Average Score	2	4	2.5

There is no consistent international definition of "fire protection engineers" and subsequently the role and level of training of "fire protection engineers" or "fire experts" differs country to country. In most cases, approved professional engineers with experience in the field of fire protection engineering are considered "fire protection engineers," even if they do not have formal education in the subject. Only a small minority of countries in the international community have programs at the university level that are dedicated to the education of fire protection engineers. Of those countries, only a small number have programs which teach the fundamentals of the PB approach such as fire dynamics. The growth and development of a new engineering field is greatly influenced by the capacity to educate new engineers and train previously established engineers. The revolutionary field of PB design is no different. Performance-based design relies heavily on not only the education of fire protections in areas such as fire dynamics but also experience reviewing and approving PB fire safety plans which were designed in accordance with PB fire safety codes. The sustained development and implantation of PB fire safety codes will not be possible unless the international educational capacity of the field increases substantially.

Of the three countries under review, Poland has the highest current capacity for formal fire protection engineers with a "Fire Protection Engineering Education" score of 4. The high score was based mostly on the country's Main School of Fire Services. However even the Main School of Fire Services does not have a curriculum devoted strictly to teaching the Performance-Based approach which kept Poland from receiving a higher score. While Poland ranked first among the three countries, Korea possesses great potential to establish and quickly expand its capacity to educate formally educated fire protection engineers. The country of Korea received a "Fire Protection Engineering Education" score of 2. While Korea's secondary-education system contains 70 individual departments, connected with various universities and community colleges, which offer programs in the realm of fire safety, none offer the fundamental courses necessary to gain a basic understanding of PBD. As Korea approaches completion of the transition of the country's fire safety codes to performance-based, the demand for professions experienced with PBD will increase dramatically. The increased regulatory and market demand will force the 70 Fire Safety departments of Korean universities and community colleges to expand and update their curriculum.

Comparing the secondary education system of Korea to Poland exposes a drastic inequality of engineering capacity. The geographic menacing country of Poland has only one institution which specializes in fire safety, while Korea possess seventy fire safety departments attached to various secondary-educational institutions. Even if only a portion of Korean Fire Safety programs develop courses and majors dedicated to PBD fundamentals, Korea could easily surpass Poland in fire protection educational capacity.

The country of Brazil, which received a "Fire Protection Engineering Education" score of 2.5, has had promising developments in the area of fire safety research. As mentioned above, a laboratory established in a joint effort between the Institute of Sao Paulo State (IPT) and the National Institute of Standards and Technology (NIST). Research in topics related to PBD such as smoke movement is being conducted in Brazil. Although, progressive research is being performed in the field of PBD in Brazil, the country's score was influenced most by the fact the lack of programs dedicated to fire protection education. The secondary-education system of Brazil currently possesses only one undergraduate program devoted to fire safety. Established by Professor Pignatta, the program is offered at the Sao Carlos School of Engineering. Although Poland and Brazil technically both have only one fire safety program at the university level, Poland has an entire institution devoted to the subject while Brazil only has one department specializing in the topic of fire safety. Additionally, while the level of the curriculum for Brazilian and Korean fire safety programs appear to be relatively comparable, Korea possesses 70 fire safety programs while Brazil only possesses a singular undergraduate discipline for fire safety.

The respective ranking and Fire Protection Engineering Education Score of the countries under review is as followed: Poland in first with a score of 4, Brazil in second with a score of 2.5, and Korea in third with a score of 2. The scoring discrepancy and ranking is slightly deceiving as the programs of the three "developing" countries are separated mostly by the presence of PBD fundamentals in the curriculum of Polish fire safety programs and the lack of these fundamentals incorporated into Brazilian and Korean fire safety programs. The process of implementing courses such as fire dynamics, which are essential to training engineers in the PBD approach, into fire safety curriculums is expensive and requires the consultation of highly experienced professionals. However these curriculum modifications are crucial to establish and support a properly implemented national PB fire safety code system.

4.4.2 Current Situation of Fire Protection Engineers

4.4.2.1 Korea

Current Situation of Fire Protection Engineers Score: 2

Korea is assigned a score of 2 for the Current Situation of Fire Protection Engineers category. As Korea has already implemented and established PB codes, it is essential that Korea takes a huge step forward by establishing proper fire protection programs and produce well educated fire protection engineers. Many have shown concerns that implementing performance based design could actually result in designs that are not adequate for fire safety. With graduates from a national fire protection engineering programs in place, Korea won't have to rely solely on PE certified engineers or foreign educated fire protection engineers to perform PBD.

4.4.2.2 Poland

Current Situation of Fire Protection Engineers Score: 3

The lack of proper training in the evaluation and hypothetical approval of PB fire safety plans causes insufficient and inconsistent levels of review of the plans. The lack of training causes "fire experts" in Poland to either rely on trust of a particular engineer's experience or the "fire expert" performs a limited amount of simple checks on the aspects of the PBD which the particular "fire expert" comprehends. Both of these short-comings in the approval process leads to the majority of the fire safety plans for projects being of low or insufficient standards.

4.4.2.3 Brazil

Current Situation of Fire Protection Engineers Score: 1

Although Brazil has shown signs of development in the research of fire, there is still not enough emphasis placed on the development of performance-based codes or providing engineers with a scientific knowledge of fire. The fire department generally consists of civil engineers who are familiar with the structural aspect of the building but cannot predict smoke movement or egress flow. For this reason, Brazil is assigned a score 1 for the Current Situation of Fire Protection Engineers category.

4.4.2.4 Analysis of Scores and Ranking of Current Situation for Fire Protection Engineers

	S. Korea	Poland	Brazil
Current experience of FPE's with PBD	2	3	1
Consistency of training level throughout country	1	3	1
Average Score	1.5	3	1

The lack of an international definition of "fire protection engineers" and subsequently the role and level of training of "fire protection engineers" or "fire experts" makes assessing the current situation of fire protection engineers challenging. The lack of programs which define and educate fire protections engineers in the international community, which was analyzed in the previous section, often requires PE certified engineers to perform and review PB fire safety plans. This trend not only is extremely hazardous to the potential occupants of a future structure in the design phase of construction but it also limits the advantages of the PBD approach which can be utilized.

Therefore the current situation or climate of fire protection engineers must be one of constant progress in a country which is attempting to transition to PB national fire safety codes. While the first step of a reforming the atmosphere of a nation's fire protection engineer population is the educational programs which teach potential fire protection engineers the fundamentals of PBD, establishing a minimum level of training and expertise for fire protection engineers working in the industry is crucial to the development of a nation's PB fire-safety codes. Without the willing support of a country's fire protection engineers to accept the PB approach, PB codes would become useless. The regulatory transition to PB fire safety codes is only one aspect of a country's general shift in fire protection regulations. Application and implementation of the newly introduced PB codes by already established professionals in the construction sector is necessary.

Out of the three "developing" countries under review, Poland has the most advantageous situation of fire protection engineers for a future transition to PB fire safety codes. The closest form of "fire protection engineers" in Poland is "fire experts." The Polish "fire expert" is a licensed official who must pass a series of difficult exams in order to receive the accreditation to review and approve fire safety designs for construction projects. The "fire expert" regulatory system is effective in form but the current implantation is flawed because the training for reviewing the PB process is not taken into consideration. Because of this void in the regulatory system, "fire experts" make severe lapses in the review of PB fire safety reports. While Poland received a "Current Situation of Fire Protection Engineers" score of 3, the lack of proper training concerning PBD must be remedied as soon as possible.

The country of Korea reviewed a "Current Situation of Fire Protection Engineers" score of 1.5 because most of the PBD work is performed by PE certified engineers but there is not accreditation system established to regulate who conducts the work. While PE certified engineers have the potential capacity to perform Performance-Based Design work, there is an amount of additional education required to properly conduct the practices of PBD. Korea could learn from Poland and adapt a similar series of tests which establish a minimum level of knowledge in the field of fire protection systems. The addition of tests would ensure a relative level of consistency of work conducted by engineers in the field. Similar to the issue of Fire Protection Engineering Programs, Korea has an above average capacity and potential to conduct PBD work as PE certified engineers are already performing the work but the industry must be regulated in order for a full scale transition to PB fire safety codes to be successful.

The country of Brazil received a "Current Situation of Fire Protection Engineers" score of 1 because of the fact that while the country has shown promise in the research of fire safety, there is not great effort made to promote the development of PB fire safety codes in the country. Very similarly to Korea, the role of fire protection engineers in Brazil is filled by engineers. In Brazil's case, the vast majority of individuals conducting fire protection and safety work are civil engineers with more experience with the structural aspects of buildings and little to no comprehension of PBD aspects such as smoke movement or egress. Brazil could also learn from Poland and adapt a series of tests to establish a minimum, consistent level of fire safety for professions in the industry.

The respective ranking and “Current Situation of Fire Protection Engineers” Score of the countries under review is as followed: Poland in first with a score of 3, Korea in second with a score of 1.5 and Brazil in third with a score of 1. The current situation of Fire Protection engineers is more advantageous in Poland than in Korea or Brazil because Poland has an established regulatory structure for certifying “fire experts,” the country’s version of fire protection engineers. However, the system is not updated to include PBD aspects of fire safety and therefore a gray area has formed and gross over-views occur in the approval procedure of PB fire safety reports. All three countries must develop an updated regulatory system for fire protection engineers in order to establish a minimum level of training in the field and guarantee that all aspects of the PB codes are met by a particular fire safety report for a building.

4.4.3 Market and Regulatory Needs for Education

4.4.3.1 Korea

Market and Regulatory Needs for Education Score: 5
Korea was assigned a score of 5 for the Market and Regulatory Needs for Education category. As stated numerously in previous chapters, Korea will keep growing vertically. With plans in place for even more high-rise and complex buildings, the construction market will definitely generate great opportunities to fire protection engineers as PBD codes require buildings of more than 30 stories high to use PBD. Although such jobs are being taken on by PE licensed engineers and foreign educated Korean fire protection engineers, the number is not enough.

4.4.3.2 Poland

Market and Regulatory Needs for Education Score: 5
The country of Poland would require both the short-term assistance of fire protection engineers and consultants to reform their National Technical and Building Regulations to be performance-based and long term employment of fire protection engineers to perform day to day tasks involved with performance-based regulations including examining design plans.

4.4.3.3 Brazil

Market and Regulatory Needs for Education Score: **5**
The combination of a rapidly growing economy and the urgency to find a solution to informal settlements places an emphasis on the market’s need for a performance-based system that can be cost-effective and improve safety. The financial factor is capable of playing a big role in the construction of high-rise buildings to improve the quality of the favelas and given the disastrous fire history of Brazil, performance-based codes can also improve the safety of high-rise buildings. As a result, Brazil is assigned a score of 5 for this category.

4.4.3.4 Analysis of Scores and Ranking for Market and Regulatory Needs for Education

	S. Korea	Poland	Brazil
Market need for educated FPEs	5	5	5
Regulatory need for educated FPEs	5	5	5
Average Score	5	5	5

All three of the "developing" countries under review, as mentioned throughout the report are experiencing dramatic economic growth and subsequent increase in the number of "prestigious" buildings being constructed within their borders. This chain reaction is one of the driving factors which have been identified for a transition to a PB safety code system. This stimulation of the construction industry often tests the limits of the current fire safety codes and exposes areas of necessary attention. The short comings of obsolete fire codes causes tension, time delays, cost increases, and general industry unattractiveness for the country's construction industry which is often a key aspect of the country's overall economy. Therefore a country wants to make the fire safety codes flexible so these "prestigious" and "cutting-edge" buildings can be constructed as efficiently and quickly as possible. However, attempts to improve constructability cannot sacrifice the necessary level of fire safety in a building, this is where the PBD approach is utilized. This desire for PB fire safety codes is considered the market need for a country. In order to conduct PBD for construction projects, well-trained and experienced fire protection engineers are necessary. Professions who can perform PBD reports are in great demand internationally and a country must develop their own way to educate fire protection engineers. This demand is considered a country's market need for PB fire protection education.

The market need for PB fire safety codes and education has a direct correlation to the regulatory need for PB fire safety codes and education. As the number of PB fire safety designs in a country increases, the demand for well-trained fire protection engineers to review and approve these designs increases. Therefore the need for proper educational programs for fire protection engineers in a country increases also. Both market and regulatory need for education are crucial to a country's transition to PB fire safety codes because they justify the allocation of great amounts of money and man power to the process. One of the driving factors behind the increased popularity of PBD is the international community's general shift to PBDas countries attempt to emulate what neighboring countries are doing. Market and regulatory needs for performance-based codes and the subsequently provoked market and regulatory need for the education of its professionals in the new engineering approach rationalizes a nation following the international trend and transitioning to PB fire safety codes. All three of the "developing" countries under review received a "Market and Regulatory Need for Fire Protection Engineering" score or 5 because they are all experiencing the economic chain reaction outlined above.

4.4.4 Education and Market Competency Scores

	S. Korea	Poland	Brazil
FPE programs	1	4	2
FPE research	3	4	3
Current experience of FPE's with PBD	2	3	1
Consistency of training level throughout country	1	3	1
Market need for educated FPEs	5	5	5
Regulatory need for educated FPEs	5	5	5
Average Score	**2.83**	**4**	**2.83**

4.4.5 Overall Education and Market Competency Score Analysis

The overall average score for Education as a driving factor for a nation's transition to PB fire-safety codes takes a number of dynamics into consideration while computing the score. The ranking for the overall average score for the three "developing" countries in question was Poland in first with a score of 4 and Korea and Brazil tied for second with a score of 2.83. It has been declared by the grading rubric listed above that Poland has a "Significant Fire Protection Engineering Education Capacity and Market Competency," while Korea and Brazil have nearly "Moderate Fire Protection Engineering Education Capacity and Market Competency."

It is quite difficult to interpret the fire protection engineering educational capacity of a country transitioning to PB codes from a single numerical value. However it is obvious that Poland has the most advanced educational capacity for the transition to PB fire-safety codes because of the Main School of Fire Services, the certification process for "fire experts," and the fire-safety waiver clause in the building regulations. These attributes elevated Poland's overall educational score over those of Korea and Brazil by nearly one and a quarter points. While Korea and Brazil have made progress in different subdivisions of the educational rubric, both countries possess great potential to easily transform their Education Capacity. Korea and Brazil have "Extensive Market and Regulatory Needs for Fire Protection Engineering Education," but both countries must take steps to develop their "Fire Protection Engineering Education" by developing fire-safety programs which include the fundamentals of PBD. Additionally both countries must improve their "Current Situation of Fire Protection Engineers" by regulating those who perform the roles of Fire Protection Engineers in the industry.

Chapter 5: Road Map for Transitioning to PBD Fire Codes

5.1 Introduction

As mentioned throughout the report, a national transition to performance-based fire-safety codes is a multi-faceted movement which includes pressures from urbanization, fire code policies, and fire protection educational capacities. All of these trends motivate the switch from prescriptive fire-safety codes to performance-based fire safety codes. The driving factors are the first phase of the shift, with the second phase being the actual regulatory transition to the PB codes.

From the research conducted in this report, it was determined that a road map to guide countries undergoing the regulatory conversion could be developed. The *Road Map for Transitioning to Performance-Based Design Fire-Safety Codes* is both a form of recommendation for countries considering a potential revision of fire-safety codes and a meter to gauge the progress of a "developing" country as it attempts to transition to performance-based fire-safety codes. The steps of the road map may not necessarily be completed sequentially because the transition process for each "developing" country will be unique. Instead the *Road Map for Transitioning to Performance-Based Design Fire-Safety Codes* is a form of checklist as countries undergo regulatory system transition.

5.2 Road Map for Transitioning to PBD Codes

National Uniform Code

- Create a uniform, nationally-consistent building code which combines building and fire-safety regulations into one guideline

Regulatory Authority

- Establish a Regulatory Authority to enforce newly implemented fire-safety codes

Educational Capacity

- Develop educational capacity of fire protection engineering fundementals

FPE Certification Program

- Establish a certification program to produce standaridized Fire Protection Engineers

Institute Waiver Clause

- Establish the option within fire-safety codes to utilize alternative methods to ensure minimum fire safety levels are met

PBD to Industry

- Promote a performance-based design approach to construction industry professionals

Introduce Complete PBD System

- Reform national fire-safety codes to include a complete set of performance-based provisions

5.3 Evaluation of Road Map for Transitioning to PBD Codes

The transition process for any “developing” country attempting to transition to performance-based fire-safety codes will be unique to that particular country. However a universal set of recommendations for countries contemplating the switch to a PB code system will help provide an estimate of the measures necessary for such a transition to be successful. Additionally a universal set of recommendations will allow evaluate the progress and compare countries in the midst of transitioning to PB fire safety codes.

Chapter 6: Conclusions and Recommendations

Through this research, driving factors to transitioning to performance-based fire codes were identified as urbanization, fire code policies and educational and marketing competence. Korea, Poland and Brazil, all countries looking to or are on the phase of transitioning to PB codes, were assessed based on the three driving factors. Final scores of the assessment is presented in Section 6.2 and recommendations for moving forward based on the assessment results and the road map to successfully transition and implement PB fire codes for Korea, Poland and Brazil are presented in Section 6.3.

6.1 The Driving Factors for Transitioning to PBD Fire Codes and Their Effects

6.1.1 Urbanization

It was found that urbanization of a country could set the tone for transitioning to PBD fire codes. Urban settings are typically characterized by vigorous economic activity, high population density. These characteristics often lead to the construction sector delivering high-rise and large complex buildings as well as new infrastructure to meet housing and transportation demands. Often times, prescriptive designs are insufficient for high-rise or large complex buildings, setting the tone for implementation of PBD fire codes.

6.1.2 Fire Code Policies

It was found that with increasing urbanization, the significance of fire code policies is greater. As previously discussed, this is a result of urbanization and higher and more complex buildings. PB codes are argued to be the safer and more economic option. However, fire code policies to include a performance-based option have not been developed at the rate at which the new structures were being constructed. This shows that regulatory policies matter, particularly with respect to uniformity of implementation and enforcement, and having suitable infrastructure to support a performance-based system.

6.1.3 Education and Market Competence

It was found that an appropriate level of engineering competence in fire protection engineering is needed for a successful performance code and design environment. While different countries may be proceeding at various levels, the educational infrastructure is essential for success.

6.2 Final Scores Compilation

	S. Korea	Poland	Brazil
Urbanization	4.875	3.5	4.25
Fire Code Policies	3.5	3.17	2.83
Education and Marketing Competence	2.83	4	2.83
Average Score	**3.735**	**3.556**	**3.303**

6.3 Recommendations Moving Forward

6.3.1 Recommendations Moving Forward For Korea

Using the Road Map to evaluate Korea shows that there are large gaps that must be filled to successfully transition to and implement PB fire codes. While Korea has already gone on to the last step for the Road Map by introducing a set of PB codes recently, none of the steps prior to this final step have seemed to been properly touched upon. This was also highlighted in the final assessment score of 3.735. The fire code policies and education marketing competence scores were low compared to the urbanization score. The urbanization score was extremely high, substantiating for the fact the due to the urban settings, need for PB fire codes is high, and there is necessary capital to support this movement. The analysis of the final assessment score indicates that there is room for improvement especially in the areas of fire code policies and education and marketing competence areas.

There is one national fire code in Korea. However, there also exists one national building code which is completely separate from the fire code. Because of this separation and poor coordination between the organizations in charge of each code, great confusion has been caused to building designers. There are attempts currently to minimize the differences between the two codes and more coordination and cooperation should see this issue out for a comprehensive building and fire code.

Although the fire marshals review fire safety designs, their influence goes only so far as to being allowed to voicing their opinions only to the government officials. The government officials are the ones who can reject applicants for building permits and might the opinions of fire marshals are only considered as advice to the government officials. Fire marshals should be able to reject building permit applications if the fire safety designs are deemed insufficient. To further support this claim, PBD requires great knowledge of fire behavior and risk identification. Hence, government officials, who are by no means experts in the field of fire protection engineering, might end up making poor decisions which may result in fire hazards, jeopardizing the implementation of PB codes. This authority of final decision making in terms of building permit approval process should be shared between the government officials and fire marshals.

There are no nationally trained fire protection engineers in Korea currently, and there will be none in the near future as well since no fire protection engineering program exists in Korea. To successfully implement PBD, the availability of fire protections is quintessential. Even if there may be a well-established set of PB fire codes, its actual implementation is nullified if there are no fire protection engineers to actually carry out the designs. The government should seek to create fire protection engineering programs in the near future to reap the benefits and to maximize the potential of the newly introduced PB fire codes.

Only those who are considered experts should be allowed to perform PBD. Those individuals could be designated as graduates of fire protection engineers. However, there should also be certification programs that give certain individuals licenses to perform PBD. Those who may be possible targets for the certification programs may be people who may have worked in the fire industry long enough to have gained sufficient fire protection engineering knowledge through experience.

The fire code only allows certain types of structures to be of PBD. However the codes should be amended such that any type of structures where prescriptive fire codes may not be sufficient should also be allowed to be designed using the PB approach.

It seems that PBD fire codes have been well publicized and promoted to the public as PBD codes have already been introduced in Korea. Now it is time to deliver and this can be done by producing highly qualified fire protection engineers through establishing fire protection engineering programs and successfully implementing the PBD codes.

6.3.2 Recommendations Moving Forward For Poland

The evaluation of Poland using the Road Map and Scoring Rubric constructed for this report illustrates promising but incomplete efforts to transition the country's national fire safety codes to a performance-based system. While the country of Poland possesses aspects of five out of the seven elements outlined in the Road Map above, each of the six aspects is not currently completely developed.

Starting with the "National Uniform Code" phase, Poland's fire safety codes are nationally-based but they are not uniform because they are separated into two different documents: the Building Regulations Act and the Fire Safety Act. The "National Uniform Code" phase of the roadmap will not be concluded until the two sets of codes are consolidated into a singular comprehensive set of codes.

The second phase of the Road Map, "Regulatory Authority," is closer to completion as the State Fire Service is a well-organized body with an established system to implement and enforce fire safety regulations. The inspection and approval system are also tailor made for the adaption of Performance-Based codes. However this conversion has not completely occurred, with inconsistent levels of PBD training and evaluation practices throughout those who assess fire safety plans for the State Fire Service. Further mandated education on the fundamentals of performance-based design will resolve this issue.

This training with the essentials of PBD will be conducted by the Main School of Fire Service, one of Poland's most important tools in the transition to Performance-Based fire-safety codes. While the Main School of Fire Services does currently teach its students some components of the PBD approach, there is not an established program dedicated to the education of Performance-Based Design. The Main School of Fire Services has the potential capacity to offer the necessary training for fire protection engineers in the area of PBD. But a separate program must be organized to provide a consistent level of education.

The trend of partial completion continues with the fourth phase of the Road Map, "Fire Protection Engineer Certification Program." Poland has an established series of tests to regulate those capable of performing the tasks of a Polish "fire expert," however the program does not cover any aspect of PBD. Because of this void in testing, an inconsistent level of competence concerning PBD exists throughout the country. This deficiency of training causes inconsistencies in the evaluation process of fire-safety plans. In order for the "Fire Protection Engineer Certification Program" to be sufficient a transition of the fire –safety codes to Performance-Based regulations, the regulatory tests must include aspects of PBD.

The fire-safety codes of Poland do possess a waiver clause which allows exceptions to the prescriptive codes as long as the alternative options meet the required levels of fire-safety. Often PBD methods are utilized verify this necessary level of fire-safety. While the waiver clause does exist in Polish fire-safety codes, the country does possess the required educational or regulatory capacity to evaluate these PBD in the approval process of the State Fire Service.

Before Poland commences a full-scale attempt "Promote PBD to Industry" and "Introduce Complete PBD System," phases six and seven of the Road Map, the necessary reforms to the elements listed above must be completed. While the country of Poland has a great framework already established for a transition to PB fire-safety codes, the elements must be updated to handle the increased complexity of PBD.

The country of Poland received an "Overall Average Score" of 3.556 for the driving factors for a transition to a PB code system. The score of 3.556 takes into consideration Poland's current urbanization trends, fire code policies, and fire protection engineering capacity. The application of the "Overall Average Score" value is the overall capacity for a "developing" country to transition to PB fire safety codes on scale of one through five. With a score of 5 meaning the country in question currently possesses an "extensive capacity for a transition to PBD" and a score of 1 meaning the country in question currently possesses "no capacity for a transition to PBD." As one can see, Poland received an exceptional "Overall Average Score," meaning the country has a capacity ranging from moderate to significant. However there still are several crucial areas which need to be addressed before a complete transition to PB fire-safety codes is practical. The main area of concern for Poland, which is impeding a shift to PBD, is the sustained growth of the country's economy.

The continued growth of Poland's economy depends heavily upon the level of foreign investment in the country. Foreign investment in Poland, which increased after 2004 because of Poland's admission into the European Union, has stimulated a number of industries in the Polish economy, especially the construction sector. International companies are positioning themselves in Poland because of the country's prime topographic location and invaluable natural resources. However these assets of Poland cannot be fully capitalized upon until the nation's infrastructure system is drastically updated. The problems and inadequacies of Poland's current road and rail systems have been outlined above. But the lack of roadways throughout the country, slows the movements of commodities along with restricting the accessibility to Poland's vast natural resources. In order to attract the maximum amount of foreign investment in Poland, the country must make great efforts to improve its infrastructure flaws.

The progression of Poland's transportation system will accelerate the rate of urbanization as an increased number of people can travel more efficiently to the urban epicenters of Poland. The improved infrastructure will also allow the full potential of Poland's economy to be reached which will further stimulate positive urbanization. The increased urbanization of Polish cities because of improvements to the transportation system will quicken the chain reaction which drives the transition to a Performance-Based fire-safety code system.

6.3.3 Recommendations Moving Forward For Brazil

Evaluating Brazil with road map shows that Brazil has a random pattern of progression without completing fulfilling any step. This resulted in Brazil having the lowest score of 3.303 with having the lowest scores for both fire code policies and fire education. Despite having the biggest economy, Brazil could not claim the highest score for urbanization as the inequality in wealth distribution and the resulting informal settlements took its toll. However, because it has a relatively high urbanization score, the need for PBD fire codes as well as the economic support for this transition is emphasized. However, it is puzzling to see Brazil obtain such low scores and heavily point out that Brazil has great need to improve in the areas of fire code policies and education.

Brazil should compile the different state codes into one national fire code. This is important as produces clarity in the language, convenience for builders to build in different states and makes the process of updating and improving codes smoother. There were efforts to compile one national fire code in 2006 without success. The first step in the roadmap could not be accomplished. As a result, it is deduced that Brazil is lagging behind in the progression to PBD fire codes even though the rapid urbanization in Brazil stresses the importance of the improvement in fire codes.

Brazil's does not have a central power in the regulatory structure which results greatly affects the transition to performance-based design. Moreover, the ABNT which consists of the Building Department, public works/ ministries, the Fire Department, professional associations, Professors/ Universities, manufacturers, testing labs, independent engineers/ architects/ technicians, insurance companies and builders and users in the decision making process. There is skepticism of whether interests of the decision makers who are from the industry could prioritize industry concerns over public concerns. The approval of the Technical Committee in ABNT could makes the codes adopted through municipal or state laws.

The curriculum in Brazil should emphasize the training of fire protection in Brazil as there is no fire protection engineering program in Brazil. The success of PBD relies on the knowledge of fire and therefore, PBD cannot be implemented when there is no trained engineer to design the buildings. Although universities are introducing a fire engineering program in the curriculum, the government should encourage this movement that will encourage PBD codes which is a safe, economical and flexible approach. Proceeding with the progression of PBD, the government should then install a certification program that confirms the ability of an engineer to determine the safety of a PBD building. Because Brazil has already established the NBR 15.575/2008 that is Brazil's first performance-based standardization, and when there are highly qualified fire protection engineers, the safety, fiscal and flexibility benefits should be promoted to the public in order to receive the backing of stakeholders in the industry as well as have public awareness that is essential for implementing a system of PBD codes.

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Appendices

Appendix A: Detailed Information on Korean Fire Code

A.1 Overview of Fire Code

Fire Safety Act

- Fire Safety Act Enforcement Ordinance
- Fire Safety Act Enforcement Regulation
- Fire Safety Act Enforcement Ordinance Separate Note
- Fire Safety Act Enforcement Regulation Separate Note
- Fire Safety Act Enforcement Regulation Template

Fire Protection Systems Construction Act

- Fire Protection Systems Construction Act Enforcement Ordinance
- Fire Protection Systems Construction Act Enforcement Regulation
- Fire Protection Systems Construction Act Enforcement Ordinance Separate Note
- Fire Protection Systems Construction Act Enforcement Regulation Separate Note
- Fire Protection Systems Construction Act Enforcement Regulation Template

Fire Protection Systems Installation and Management and Safety Provisions Act

- Fire Protection Systems Installation and Management and Safety Provisions Act Enforcement Ordinance
- Fire Protection Systems Installation and Management and Safety Provisions Act Enforcement Regulation
- Fire Protection Systems Installation and Management and Safety Provisions Act Enforcement Ordinance Separate Note
- Fire Protection Systems Installation and Management and Safety Provisions Act Enforcement Regulation Separate Note
- Fire Protection Systems Installation and Management and Safety Provisions Act Enforcement Regulation Template

Hazardous Material Management Act

- Hazardous Material Management Act Enforcement Ordinance
- Hazardous Material Management Act Enforcement Regulation
- Hazardous Material Management Act Enforcement Ordinance Separate Note
- Hazardous Material Management Act Enforcement Regulation Separate Note
- Hazardous Material Management Act Enforcement Regulation Template

A.2 Breakdown of Activities

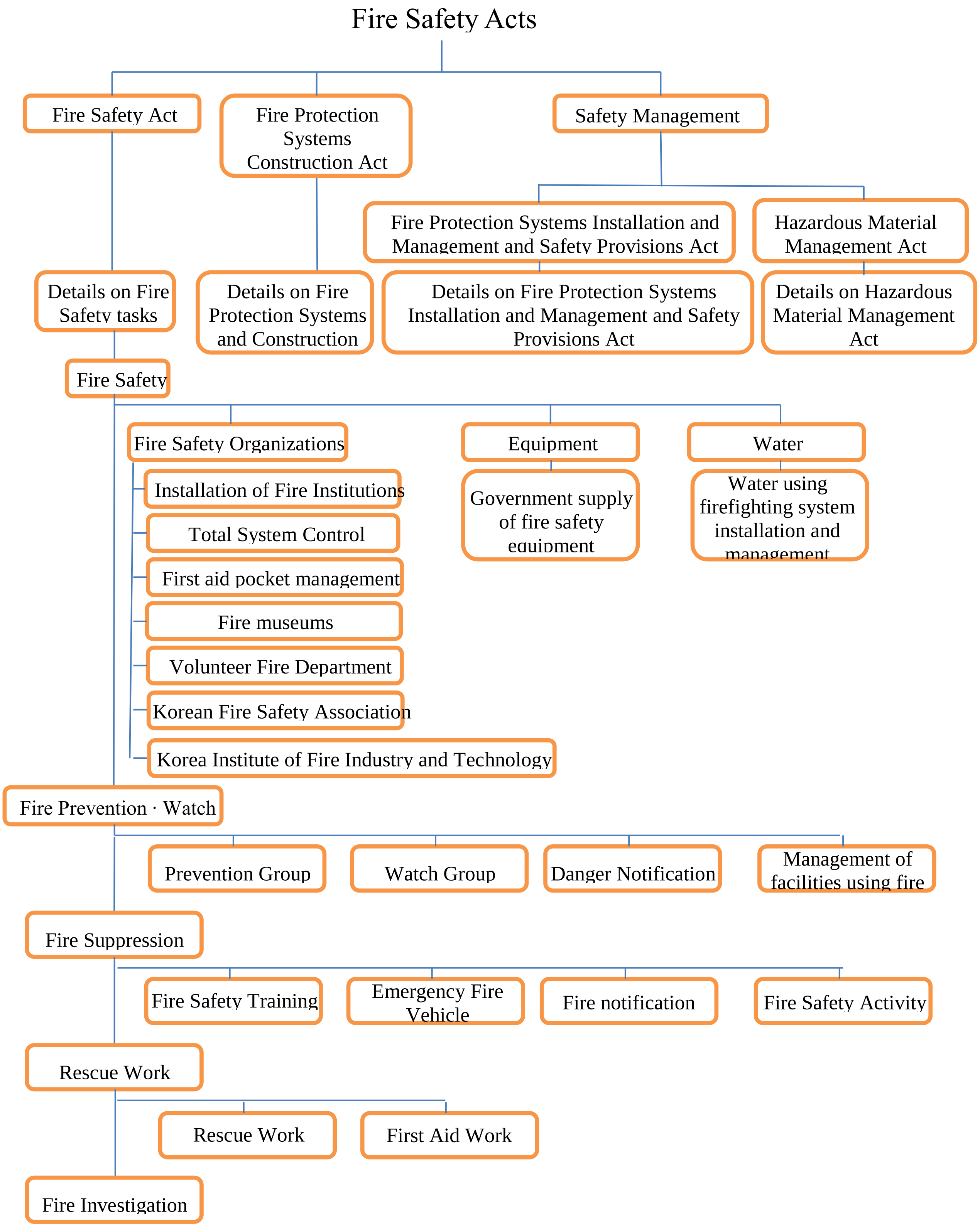

Figure 16: Breakdown of fire safety activities

A.3 Fire Code and Building Code Comparison

Table 7: Korean Building Code and Fire Code Comparison

Fire Progression	System Type	Prevention Action	Building Regulation	Fire Regulation
Alarm System Ignition ↓ Notification	Active System	- Automatic fire detection system	-	NFSC 203
		- Emergency alarm system		NFSC 201
		- Emergency Mass Notification System		NFSC 202
		- Electrical alarm system		NFSC 205
Early Suppression Self-suppression ↓	Active System	- Extinguishing devices (such as portable extinguisher)	-	NFSC 101
		- Sprinkler system		NFSC 103
		- Fire hydrant (occupant use hose)		NFSC 102
		- Water spray extinguishing system		NFSC 104
Evacuation Plan Preparing and executing evacuation plan ↓	Active System	- Evacuation Tools	-	NFSC 301
		-Exit sign		NFSC 303
		- Emergency lighting		NFSC 304
	Passive System	- Direct staircase installation/configuration	Enforcement Ordinance Act 34	NFSC 501A
		- Evacuation staircase/outdoor staircase	Enforcement Ordinance Act 35	
		- Special evacuation staircase	Enforcement Ordinance Act 35	
		- Exit Discharge	Enforcement Ordinance Act 39	
		- Rooftop and helipad	Enforcement Ordinance Act 40	
Combustion Expansion Prevention Retarding and preventing combustion expansion ↓	Semi-Active System	- Fireproof shutter	Enforcement Ordinance Act 46	-
	Passive System	- Fireproof structural system	Enforcement Ordinance Act 56	-
		- Fireproof Construction	Enforcement Ordinance Act 2	
		- Fire partition	Enforcement Ordinance Act 46	
		- Fire door construction	Enforcement Ordinance Act 64	
		- Firewall	Enforcement Ordinance Act 57	
		- Interior finish materials	Enforcement Ordinance Act 61	
		- Fire resistance treatment	-	NFSC
Fire Fighting Activity Supply System Fire fighting ↓ Suppression	Active System	- Standpipe	-	NFSC 502
		- Hose connection		NFSC 503
		- Water (available) for fire-fighting		NFSC 402
		- Smoke exhaust system	Enforcement Ordinance Act 51, 87	NFSC 501
		- Ventilation system, area	-	NFSC 501
		- Emergency lift	Enforcement Ordinance Act 90	NFSC 501
	Passive System	- Dead-end corridors	Enforcement Ordinance Act 3	-

A.4 PBD Code Analysis

All construction type that falls under the category listed on Article 2 Clause 2 of the Fire Safety Construction Act must be designed using performance based design codes. The code specifies for the following buildings to implement PBD codes.

- Structures exceeding 200,000 m^2 in total floor area
- Structures over 100 m in height as well as structures with more than 30 stories (including underground floors)
- Railroad, high-speed railroad and airport facilities
- Any structure consisting of 10 or more movie theaters

However, in other countries where performance based design method has been integrated, a freedom of either using the prescriptive codes or the performance based codes is given to the designer. This freedom is not allowed in Korea as performance based design option is mandatory and only allowed for the limited types of construction allowed by the law. This alone is a controversial issue in the early stages of implementing performance based design.

Although a broad range of construction falls under the performance based design category, there is a lack of established fire protection engineers who are capable of actually conducting performance based design and a set of well-established and clear procedures to ensure that the designs are adequate to meet the fire safety requirements. From this perspective, it seems more suitable to change from a mandatory approach to being able to select between prescriptive or performance based. Many have shown concerns that implementing performance based design could actually result in designs that are not adequate for fire safety. The code should state that certain type of construction can use performance based design rather than stating that certain constructions must use performance based design.

The statement in the code which specifies only a certain type of construction to be allowed to use performance based design puts limitations on other constructions that may benefit by using performance based design rather than prescriptive design. For example, if fire protection systems are installed in a nuclear power plant with the prescriptive codes of the Fire Protection Systems Installation and Management and Safety Provisions Act, it could cause serious problems in terms of preventing radiation leak. There are several common features in terms of interior layout between nuclear power plants and airports or train stations, with only the latter two falling under the performance based design criteria. It is critical to identify which constructions are not suitable to prescriptive codes.

Article 2 Act 2 of the Fire Safety Construction Enforcement Act states performance based design is only applicable to new construction. This prohibits old construction to implement performance based design while going through renovation, remodeling or relocation even if the construction falls under the performance based design category. According to the clause, those constructions that go through renovation, remodeling or relocation can no longer be in the new construction category. Therefore, even if a construction had used performance based codes to build it in the initial stages, if it goes through renovation, remodeling or relocating, performance based design can no longer be implemented to the construction as it is not considered a new construction and must switch to the prescriptive codes. Performance based design must not be limited to only new construction but to all construction. Along with this change, another law that states that performance based design shall not be applied to constructions that were built before the performance based design codes became effective. This will prohibit old buildings designed using the prescriptive codes from having to switch to performance based design.

A.5 Fire Disaster in History and Its Effects on the Fire Code

On March 10th, 1958, the first ever Fire Services Act was enacted. The Fire Services Act (Act No. 485) consisted of 54 provisions and clauses which attempted to prevent, protect and suppress fire, wind and snow to protect life and property while minimizing the damage. However, convenience and capital became the number one essentials of life with the economic boom and the new found affluence. Consequently, safety became a forgotten issue in the minds of many Koreans. As times changed so did the fire safety circumstances but only the fundamentals on which the Fire Services Act was established remained intact. The codes stayed untouched throughout the years only for the necessary ones to be modified as a result of a fire calamity. (Hong, 2009).

The deadliest building fire in South Korean history occurred on Christmas day of 1971, in a twenty-two story Daeyeongak Hotel building located in Choongmuro, Seoul. The hotel guests, who had fallen sound asleep after a night of partying on Christmas Eve, were woken up by smoke from a fire that had ignited after a propane gas explosion from the second floor coffee shop. The fire started around 9:50am and it was only a matter of time before the fire spread throughout the building which had floor carpets made of synthetic fiber and interior finishing touches completed with timber. By 11:20am, only after an hour and a half from the start of the fire, it had spread and reached the 21st floor of the building. Although every single fire truck in Seoul City had arrived to fight the fire it was an arduous task with fire fighters being poorly equipped. Water from the fire truck hoses could only reach the 8th floor and the tallest ladder rising to 32meters, could only reach the7th floor. Although helicopters from the Republic of Korea Army Air Corps and the Eighth United States Army were put into the scene to help the rescue mission, it was not easy getting in proximity to the building with strong gusts and smoke impeding the process. 38 people died trying to jump off the building, having panicked after being unable to reach other exit routes. 23 people were found dead from suffocation right next to a roof entrance door that was locked. The fire lasted for 10 hours, taking away 165 lives in total and leaving 65 injured. (Jung, 2010).

Investigations of the calamity revealed the fire ignited as gas was exposed on the Polyvinyl chloride pipe between the gas burner and the container. Use of propane gas was not universal in Korea during the time of the incident and safety regulations were not met. The gas container was stored indoors rather than being stored outdoors or inside fire proof boxes and plastic pipes were used for distribution rather than using metallic pipes. The fire that started on the 2nd floor reached the 21st floor travelling through the heating-cooling duct system. Most of the casualties had occurred to those who were trapped in floors between the 21st and the 2nd floor where the fire had started and spread to. The loss was even greater as fire alarms failed to go off during the fire and there were to fire protection systems such as sprinklers. (Seoul Daeyeongak Hotel Fire, 2010)

This incident aroused the attention of all South Koreans. Soon after, as a result of such calamity, a fire safety campaign was inaugurated and it became mandatory for all high rise buildings to be on a fire insurance plan. It also led to several revisions of fire regulations. On February 8, 1973

Fire Regulation Act 2503 was amended, giving fire marshals the authority to investigate any facility or request for documentations when needed to see the status of building maintenance. Under the new provision, the fire marshal also had the authority to ban the use of or to remove any materials deemed to be a threat on human safety during a fire. Also, occupants using acetylene, liquefied petroleum gas or any other combustible gas needed to get the fire marshal's approval prior to use. (Hong, 2009).

Fire Fighting Act 3675 was also amended on December 30, 1983. With the revision, the fire service act materialized by placing all first-aid, relief and rescue work under the fire service act. To prevent poor construction, the fire protection construction system set up changed from a registration system to a license system. To expand the distribution of fire extinguishers, the fire extinguisher sales registration system was abolished, allowing fire extinguishers to be sold freely. Also the Act enforced large accommodation facilities to install automatic fire protection systems and better evacuation tools. (Hong, 2009).

A.6 Fire Disaster Statistics

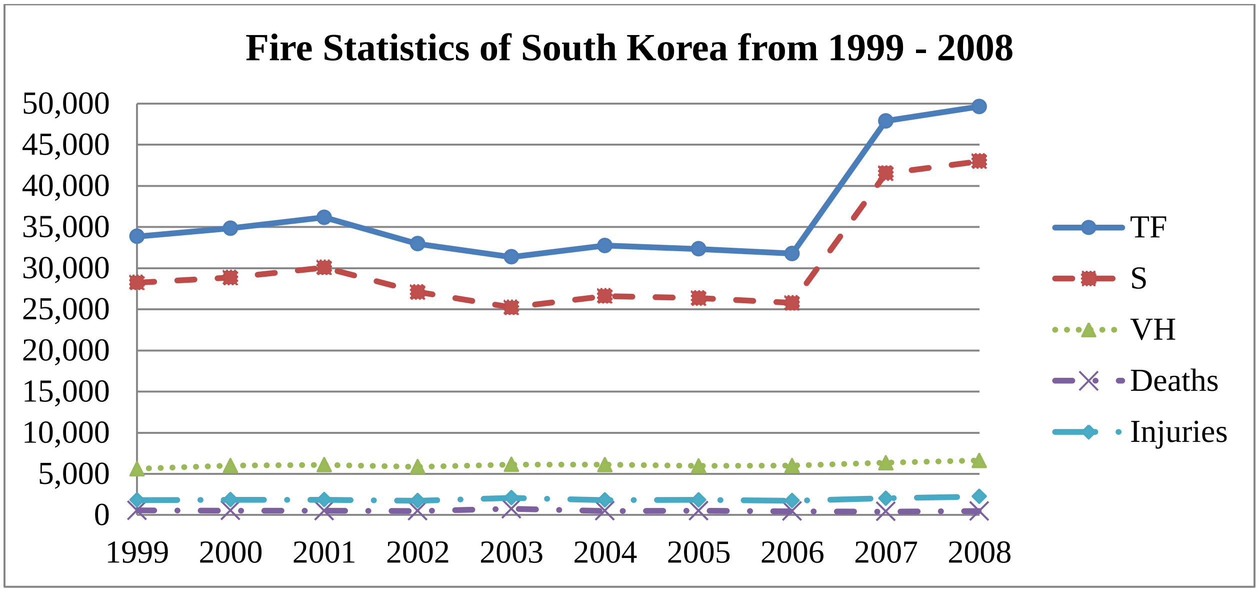

Figure 17: Fire statistics of Korea (National Emergency Management Agency of Republic of Korea)

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	IR
TF	33,856	34,844	36,169	32,966	31,372	32,737	32,340	31,778	47,882	49,631	5.2%
S	28,253	28,846	30,078	27,102	25,235	26,620	26,370	25,773	41,533	43,008	5.8%
VH	5,603	5,998	6,091	5,864	6,137	6,117	5,970	6,005	6,349	6,623	2.0%
Deaths	545	531	516	491	744	484	505	446	424	468	-1.6%
Injuries	1,825	1,853	1,860	1,744	2,089	1,820	1,837	1,734	2,035	2,248	2.6%

** TF: Total Fires, * S: Structures, * VH: Vehicles, Ships, Aircraft, etc*

** IR: Average Increase Rate during 10 years*

Appendix B: Additional Fire Code Information on Poland

B.1 Transcript of Interview with Piotr Tofilo (Professor at Main School of Fire Services)

1. **Can you please outline the regulatory structure of fire safety codes in Poland?**

Building Regulations (Parliament Act - Ustawa Prawo Budowlane) is the general act and it contains delegation for establishing a Infrastructure Minister's Decree - Technical Requirements for Buildings and their situating.

Technical Requirements for Buildings and their situating (Warunki techniczne dla budynków i ich usytuowania) is the most detailed prescriptive guidance for buildings. It contains a chapter on fire safety and protection. The subchapters are: General, Fire Resistance of Buildings, Fire Compartments and Fire Barriers, Evacuation routes, internal finishing and fixed elements, Installations and stoves, Buildings Situation, Garages, Farm buildings, Temporary buildings. Some fire related issues are raised in other chapters too, but not many.

Fire Safety Act - (Parliament Act - Ustawa o ochronie przeciwpożarowej) is the act that describes how the fire safety is organized in terms of administration, structure and roles of authorities. It contains delegation for establishing 3 Interior Minister's Decrees -

a) Fire Safety in Buildings, other Structures and Areas

b) Access for Fire Fighting Teams and Water Supply for Firefighting

c) Approval of Building Designs in terms of fire protection

Fire Safety in Buildings, other Structures and Areas - contains the following chapters: General, Forbidden activities and duties in fire safety, Dangerous materials, Evacuation, Internal firefighting water supply and provisions, Fire Protection Systems, Technical Systems and Appliances, Fire Safety Precautions during maintenance works, Fire Protection of Forests, Fire precautions in relation to crops.

2. **What are the specific reasons that the nation is transitioning to Performance-based regulations?**

Economical growth resulting from joining EU attracts large international investments (in terms of buildings) which require more flexible design approach. Prescriptive code is not flexible and archaic in its structure. It is also quite incoherent and controversial. Fire Brigade Headquarters has the biggest role in creating regulations. The team that should do that is not big and they have many regulationary obstacles.

3. **<u>What problems has fire protection engineers encountered with the transition thus far?</u>**

A. Lack of proper PB verification structure and well trained staff to check PB reports

   Currently it is Provincial Fire Brigade Headquarters (16 provinces in Poland)Fire Officers there are not well trained enough to evaluate PB design so the approvals are either done on the basis of good trust towards the particular engineer who prepared the PB fire report or it is based on simple check of report elements that are known to the verifying officer. This leads to many reports being of low standard in less developed provinces.

B. Education system in terms of PBD is not yet well developed. Various elements are taught on different courses but it is not taught as a coordinated course.

C. Lack of good literature translated into Polish

4. **<u>How has the implementation of the Eurocodes gone in Poland thus far?</u>**

From my knowledge Eurocodes are used relatively widely among civil engineers but the fire elements are less familiar to many designers.

5. **<u>How many schools teach fire protection engineering in Poland?</u>**

There is only one institution that runs fire protection engineering course (BEng and Masters) and that is the Main School of Fire Service (I am a graduate and current academic staff there since 2010). Unfortunately the teaching program is not yet converted to reflect the needs of PB design comprehensively. It contains many elements of it but students do not have many opportunities to study PBD as a system.

6. **<u>How many fire protection engineers are in Poland?</u>**

We have a system of private licensed fire experts who are a vital part of the design approval process. They have to pass difficult exams for that role and they are responsible for checking the design and approving it. Then they inform the Fire Brigade Authorities that they have approved a certain building. This is the group of people - 500 or so, out of which probably 100 is more active and the rest is doing approvals only occasionally. Out of those 100 only a part is actively trying to embrace and understand new methods to the level they know what they are doing and what are the implications and uncertainties.

There is a group of unlicensed engineers. They do just the engineering work without approvals. I do not know what the number is.

7. **<u>Do you have any data concerning the problems involved with designing skyscrapers to the prescriptive codes of Poland?</u>**

Not sure how to answer that. There are more and more skyscrapers being built in Poland and in terms of fire protection investors complain that the level of fire resistance required for tall buildings is too high (240 mins). Probably further conversation could help.

8. **<u>What are the current fire protection trends in the Polish Construction industry?</u>**

Not sure how to answer that. Probably further conversation could help.

9. **<u>What is the single biggest problem facing fire protection engineers in Poland currently?</u>**

1. Education and access to literature
2. Prescriptive fire regulations not coherent and not consulted widely before implementation

10. **<u>Do you believe there is a direct correlation between Poland's recent economic growth and a potential transition to Performance-based fire regulations in Poland?</u>**

Yes, I believe there is a direct correlation as I mentioned before. Hundreds of big shopping centers had to be built in recent decade around Poland and without performance based approach these would not be compliant with polish regulations.

B.2 History of Polish Fire Codes

While Poland was occupied by the Soviet Union, from the closing days of WWII up until 1989, the task of fire prevention in the region was handled by the USSR Ministry of Internal Affairs. The USSR Ministry of Internal Affairs also regulated civil institutions as penitentiaries, police forces, and traffic regulation. Beneath the Ministry of Internal Affairs were satellite ministries located in each of the union's republics with sections (otdely) and departments (upraveniaa) at a regional level. The ministry was composed of a Chief Department for Fire Protection which was the "supreme regulatory and supervisory agency (Simons, 1980)" in the field of fire protection. The responsibilities of the Chief Department of Fire Protection, along with its secondary departments, was outlined by the Statute on State Fire Supervision which was passed on December 26, 1977 (Simons, 1980).

With the vast majority of land in Poland rural in nature during the USSR era, the fire prevention services at a local level was handled by voluntary fire companies. The voluntary fire brigades were united under the All-Russian Voluntary Fireman's Association which was structured in the traditional USSR hierarchy, with provincial, district, city, and primary subdivisions (Simons, 1980). As outlined by the Statute of State Fire Supervision, the All-Russian Voluntary Fireman's Association operated "in close contact with the organs of the state fire inspection (Simons, 1980)."

As Poland gained its independence, the Directive of the Council of European Communities established a series of fire safety principles which were later included into the Polish Technical and Building Regulations (Cisek, Skaznik, & Cisek). These principles in there most simplified form are broken down into four requirements. First the building must be built in such a manner to limit the spread of fire to neighboring buildings. Secondly, occupants of the building in consideration must be able to evacuate or be saved in an alternative method. Thirdly, the safety of the firefighters and rescue personnel must be taken into close consideration. Finally, the ability for the structure to carry a specified load must be guaranteed for a calculated period of time. While these principles in their simplest form seem similar to performance-based regulations, in fact the code established by the Directive of the Council of European Communities is extremely prescriptive in form (Cisek, Skaznik, & Cisek).

One of the most significant events in Polish history is the country's induction to the European Union in 2004. The inclusion of Poland into the EU drastically affected the nation's fire protection atmosphere because Polish fire protection regulations must now meet the standards set forth by the EN Eurocodes. The EN Eurocodes are a "series of 10 European Standards, EN 1990-1999, providing a common approach for the design of buildings and other civil engineering works and construction products (Eurocodes Building the Future: Homepage)." The aim of the Eurocodes is to standardize the market for design services and construction materials in the EU, thus increasing the level of consistency and efficiency while simultaneously establishing a uniform level of safety in the European Union's construction sector. The Eurocodes apply directly to the structural design of fire safety for “buildings and other civil engineering works (Eurocodes Building the Future: Homepage).”

The Eurocodes were established in 1975, nearly fifteen years before Poland gained its independence, as a program in accordance with Article 95 of the Treaty of Rome. The original objective of the Eurocodes was “elimination of technical obstacles to trade and the harmonization of technical specifications by means of technical rules.” Following an international inquiry concerning modern construction codes implemented in 1980, the first Eurocodes were published in 1984 by the Commission of the European Community. The Eurocodes continued to evolve and be refined in the 1990’s, concluded by the conversion of European pre-Standard (ENV) to the European Standard (EN) subsequent to the “Commission Mandate” to the European Standardisation Organisation (CEN) in 1998 (Eurocodes Building the Future: Timeline). The first decade of the new millennium represented as time of great progress as the recommendation for the implementation and utilization of the Eurocodes were released in 2003, the Eurocodes themselves were published in 2006, and full implementation of the EN Eurocodes occurred in 2010. Full implementation, represented by the elimination all incompatible “National Standards, came at the end of the co-existence era, where the Eurocodes and a nation’s standards are used analogously (Eurocodes Building the Future: Timeline).

Current Polish Building law states:

> “buildings should be designed and constructed, taking into account a building’s expected life, in accordance with the regulations, including technical and building ones, and the principles of technical knowledge, ensuring that all essential requirements concerning, among others, fire safety principles are conformed to (Cisek, Skaznik, & Cisek).”

The process of requesting and obtaining approval from the Polish fire department for a project such as the construction of a warehouse takes on average 13 days or about 2 weeks. The plans for the construction project must first be reviewed by a licensed fire safety expert. These licensed fire safety experts are approved by the Polish General Commandant of the Governmental Fire Department and their work is overseen by the Commander of the Fire Department. In order for a project to move forward, the fire safety expert must affix an approval stamp supplemented by an approval/nonapproval clause to the project plans. Next, the agency which issues building permits must ensure that both the stamp and approval/nonapproval clause have been submitted by the fire safety expert. Finally the necessary parties must notify the governmental Fire Department of the construction project’s completion and subsequently the structure must be inspected and approved by the governmental fire Inspectorate. A process which takes on average 15 days to complete (Dealing with Construction Permits in Poland, 2011).

B.3 Problems with Current Polish Fire Codes/Eurocodes

Before the complete implementation of the Eurocodes, Poland did not have any performance-based codes for fire safety design. Because of this the vast majority of structures in Poland were designed to meet the basis of the Polish prescriptive codes and standards. However with the economic boom of the new millennium and the subsequent dramatic growth in the construction sector, an increasing number of new construction projects are encountering crucial issues during the design phase as the design team attempts to meet the inflexible prescriptive codes. The difficulties involved with designing around the strict fire safety codes lead to significant technical problems and or inflated cost. In the current Polish economy, the most important area of development for the construction sector is innovative structures which push the industry standard and "after applying these regulations for many years it is obvious that with regard to a small but very crucial group of the largest and most prestigious buildings it is not possible to design these buildings under such regulations (Cisek, Skaznik, & Cisek)." The greatest obstacle for these "large and prestigious" construction projects during the design phase is often the inability to conform to all of the prescriptive fire protection requirements (Cisek, Skaznik, & Cisek). In an extremely temperamental global financial atmosphere, it is issues such as delayed design times and budget overruns which can completely stall a large-scale construction project and scare off foreign investors. With the continued development of the Polish economy heavily dependent upon the escalating foreign investment, a general lack of confidence in the large-scale construction sector could prove very detrimental to Poland's ability to sustain such impressive economic growth.

The Eurocodes have great potential to improve efficiency and consistency in the construction market throughout the European Union and even beyond, however the implementation of the Eurocode's fire protection standards has proven to be quite difficult logistically. The harmonization of the Eurocodes and Nationally Determined Parameters (NDP) has presented great issues (Dimova S. , Pinto, Oztas, Geradin, & Altinyollar, 2007). Nationally Determined Parameters (NDP) have been created to take into consideration the varying standard of living and environmental conditions for each Member State in an attempt to produce a relatively uniform level of fire safety and flexibility in the design process. Even though there is a comparatively small number of Nationally Determined Parameters in the fire protection area, more than two thirds of them were devised from various "design cultures and procedures for structural analysis (Dimova S. , Pinto, Oztas, Geradin, & Altinyollar, 2007)." The utilization of updated NDP's will assist greatly in the comparison of the respective safety levels for the different Member States and promote progress in the fire safety of all EU civil engineering projects (Dimova S. , Pinto, Oztas, Geradin, & Altinyollar, 2007).

In terms of National implementation and the employment of the fire safety aspects of the Eurocodes, it has become evident that for many of the Member States of the EU there is a void between the fire protection regulation of the country and the Eurocodes (Dimova S. , Pinto, Oztas, Geradin, & Altinyollar, 2007). This issue has produced an inconsistent level of fire performance for the Member Nations due to an inability to "calibrate" the Nationally Determined Parameters (NDP). In order to remedy this situation it has been recommended that, "The National implementation of the Eurocodes and their correct use in the design practice require preparation and provision of background information on the recommended values of the NDPs, training courses, designer guides, worked examples, handbooks, manuals, design aids and software (Dimova S. , Pinto, Oztas, Geradin, & Altinyollar, 2007)."

It is estimated that the prescriptive-based codes for most of the Member States will transition to performance-based codes with the implementation of the Eurocodes. While the evolution towards performance-based codes will increase development in the field of fire protection technology, the trend will also require laboratory research in a multitude of areas. Professor Joel Kruppa, Chairman of the Horizontal Group for Fire design on CEN/TC250 outlined the future research requirements concerning the "nominal" fire approach as:

- Harmonized procedure to determine safety factors
- Calibration of calculation methods to test
- Thermal conductivity for various types of concrete
- Connection
- Aluminum alloys
- Effects of creep (steel, concrete) at elevated temperature
- Unbraced steel or composite frames.

Professor Joel Kruppa also estimated the future research requirements for the "Fire Safety Engineering" approach as:

- Under Real Fire Scenarios
    - Scope and limitation of models for design fires
    - Define the way to take into account, in fire development, active fire measures like detection, smoke evacuation, sprinkler, etc.
    - Spalling conditions for concrete (HSC) for various fire scenarios
    - Behavior of structural elements (concrete, steel, composite, timber)
- Under Real Fires Including Cooling Phase:
    - Determination of "real" thermal characteristics of fire protection materials.

The issues with fire protection research in the European Union stem from the lack of a specific European Technology Platform dedicated to the field of fire safety. The only place where the need for research is mentioned is the Strategic Research Agenda of the European Steel Technology Platform. However even in the Strategic Research Agenda of the European Steel Technology Platform, there is no individual “Focus Area” devoted to fire protection research (Dimova S. , Pinto, Oztas, Geradin, & Altinyollar, 2007). In order for the evolution of performance-based fire regulation in the EU to continue, new research must be completed by potentially developing “Focus Areas” on fire safety in both the European Construction Technology and the European Steel Technology Platforms (Dimova S. , Pinto, Oztas, Geradin, & Altinyollar, 2007)

B.4 Transition to Performance-Based Fire-Safety Codes

As stated above, the very prescriptive fire regulations of Poland are suffocating the "prestigious" structures sector of the country's construction industry. The conflict between the Polish building authority (Ministry of Infrastructure) and the construction industry, mainly in the design phase of projects, causes time delays and budget overruns. The Ministry of Infrastructure is described as "far too detailed and excessive (Ratajczak & Tofilo)." In an attempt to mirror other countries which are transitioning to more flexible fire safety codes in an effort to foster cutting-edge design, Poland has begun to adopt a more performance-based orientation (Ratajczak & Tofilo). The first step in Poland's transition to performance-based regulations was the introduction of a waiver clause which allows exceptions to the prescriptive fire safety regulations on a case to case basis. Performance-based codes and tools are utilized to prove that the waivered design feature will not increase the life hazard of the structure under consideration. A design team must provide alternative plans which guarantee compensation for the feature's inability to meet the prescriptive requirements. A series of performance-based fire engineering tools are utilized in order to ensure the required level of fire safety, including design calculations of evacuation conditions, efficiency of smoke management systems, smoke control systems, and computer simulations (Ratajczak & Tofilo). The country's fire protection regulations outline which requirements have the possibility to be waived.

Performance-based fire regulations are much more prominent in the Eurocodes than Polish fire codes. The Eurocodes provide two alternative designs processed, the prescriptive design approach and the performance-based fire safety design approach. The performance-based fire safety design approach meets the necessary fire resistance requirements by examining the "actions and acceptable consequences of various fire scenarios (Dimova S. , Pinto, Oztas, Geradin, & Altinyollar, 2007)." The majority of the structural fire design sections concerning materials are based off of the performance-based fire safety design approach. The performance-based approach involves "the application of engineering principles, rules, and expert judgments based on a scientific assessment of the fire phenomena and their effects (Dimova S. , Pinto, Oztas, Geradin, & Altinyollar, 2007)."

B.5 Additional Information on the Economic Growth of Poland

The international stereotypical image of Poland is that it is nothing but a large, poor land, lingers from the days of the country's communist occupation (Horse Power to Horspower). However this could not be further from the truth as Poland is emerging as one of the fastest growing markets in Europe. After gaining independence from the Soviet Union in 1989, Poland's economy remained stagnant in post-communist confusion, but the Polish market was jumpstarted by the country's acceptance into the North American Treaty Organization (NATO) in 1999. Poland gained further financial momentum after joining the European Union in 2004. Poland's economy has developed into a high- income market, ranking as the sixth largest in the European Union (Country and Lending Groups, 2010). As a matter of fact it is the only country in the EU to not only register positive economic growth in the 2006 at 1.2% but also evade decline in the national GDP (Polish Information and Foreign Agency, 2007). In 2009, the Polish GDP per a capita rose from 50% to 56%% of the European Union's Average, a record jump for the country's short but promising history in the EU. Currently Poland holds the 20th highest GDP worldwide (Skolimowski & Burg, 2009). Much of the recent economic success listed above is due in large part to Poland's recent addition to the European Union and the country's "stodgy" national banks missing the boat on the overzealous "foreign currency lending" trend which sunk the economies of close-by Latvia and Hungary (Horse Power to Horspower). In terms of politics, Poland maintains a "center-right government with a majority in parliament," which is hard to come by in countries of its kind (Pleitgen & Davies, 2011). All of these factors combine to project a very promising economic future for the once grim nation.

The past decade has provided Poland with an excellent foundation for economic development. The future holds great potential for the Polish market, but the future level of financial success will depend, largely in part, upon how heavily the country invests in it's outdated national infrastructure system. One of Poland's most valuable natural resources is its geographical location, acting as a literal bridge between the more advanced Eastern European market and the struggling Western European countries. Currently, Poland's road system is one of the worst in Western Europe with only 3% of roads meeting the standards set by the European Union. The low road network density, 1.19 km per square km along with congestion caused by increased automobile flow has slowed down the movement of people and goods thus threatening to stall the economic momentum. However great strides have already been made to improve the Polish Infrastructure as the EU has increased structural funding in the country from 2007 to 2013 produced from the EU Structural and Cohesion Fund which is designed to update transport networks, increase regional development, and promote education and environmental causes. Enhanced infrastructure would allow commodities to reach overseas markets faster while reducing costs, thus spurring economic growth for exports make up a majority of the country's GDP.

B.6 Additional Information on the Polish Construction Industry

The economic boom in Poland has not only lifted the shroud surrounding the country but also stimulated the national building industry which is crucial sector of the country's economy. Construction companies have become much more optimistic in their assessment of the current market environment. Nowhere is this trend more evident than in Poland's official capital, Warsaw. Warsaw is not only the largest city in Poland, acting as a catalyst for the once-rural country, but also the 9^{th} largest in the European Union in terms of population. The city is often called the "phoenix city" as it rose from the ashes, like the mythical fire-bird, after Adolf Hitler burned over 85% of the city during his occupation in World War Two. Poland has invested massive amounts of funds into the country's once delay-plagued infrastructure network, further enriching the environment for foreign investments (Attracting Foreign Investment, 2004). Warsaw is considered the "tallest city in Europe" with 18 of Poland's 21 skyscrapers within the city limits. Additionally the city has Construction is also underway in building and renovating soccer stadiums across the country, including the 56,000 seat National Stadium in Warsaw, in preparation for the UEFA Euro 2012 soccer tournament which Poland is hosting along with the Ukraine (Attracting Foreign Investment, 2004)

B.7 Additional Information on the Prominent Buildings of Polish Cities

There is a number of prestigious buildings located in Poland, with the majority of them in the nation's capital of Warsaw. The structure to which all others are compared to in Poland is the Palace of Culture and Science which was constructed in 1955 by the Soviet Union as a gift to the Polish people. The building is the tallest in Poland and the eight tallest in the European Union. The Palace of Culture and Science, styled like many Soviet buildings of the period, is the most visible landmark in Warsaw, surrounded by great controversy because the structure remains as a lasting reminder of Soviet dominance and oppression.

Although the Palace of Culture and Science remains the tallest building in Poland some 50 years after its construction, there are a number of projects both newly-finished and under-construction which not only drastically alter the skyline of Poland's largest cities but also illustrate the recent development of the country. The oldest of these buildings in the Warsaw Financial Center which was finished in 1998. At 165 meters, the Warsaw Financial Center is one the tallest and most modern buildings in the country, including such features as advanced safety systems.

Rondo 1: an office skyscraper with a height of 192 meters, in Warsaw, designed by Skidmore, Owing and Merril. Construction began in 2003 official opening in 2006

Sea towers: a multifunctional skyscraper which was finished in 2009. Located in the fast-evolving port city of Gdynia, the towers is the tallest building outside of Warsaw and the tallest residential building in Poland. Every apartment unit was sold before construction was completed.

Zlota 44: under construction, delayed because of the economic downturn, designed by Polish born American architect Daniel Libeskind. Designed by Orco Property group. The name is the buildings prewar address, the area was completely destroyed by Hitler. Located next to the Palace of Culture and Science. 3rd tallest skyscraper.

Appendix C: Additional Fire Code Information on Brazil

C.1 Transcript of Interview with Professor Ono (University of Sao Paulo)

Hello, Mr.Thang
I have received your e-mail and I am sorry I could not answer before,
as I have been quite busy...
I will try to give short answers to your questions, at first, OK?
Then, if doubts are left, ask me again.
* Firstly, do you have, or can you point me to where I might find, recent statistics regarding the number of fires that have occurred in Sao Paulo and Rio de Janeiro (perhaps over the last 10 years?).
São Paulo and Rio de Janeiro: You mean State or City? I have no data from Rio de Janeiro. You may try to contact the State Fire Department to get them. From São Paulo, I would say the same, today. I have the Annual White Book of São Paulo State Fire Department until 2005. From that time, I was not able to have access to it any more... You may try to get it. If you ask specific data, the may provide you easier (total number of structure fires, for example).
* Secondly, would you be able to kindly provide us with information on the current situation with building fire safety codes in Brazil, particularly with respect to the possible transition from prescriptive- to performance-based.
The fire regulation are State-based, ruled/revised by the Fire Department of each State. I cannot say about all the regulations but in Sao Paulo State, the regulation is still prescriptive. They have one article in the regulation that opens to the introduction of alternative solutions, but the FD staff are not prepared to evaluate perfomance-based/ engineering-based designs/solutions yet... They have
been very conservative on the approval of alternative solutions.
* Thirdly, how is Brazil developing codes to encompass both the high-rise buildings and the informal housing?
You mean fire codes? The fire codes do not establish/ require any fire protection for single-family houses (formal or informal). In general, protection is required to buildings over 750 m2 or over certain height (12m) or population (100 persons).
* Lastly, we are interested in the current situation with fire research and fire protection engineering in Brazil: could you update us on the current situation and outlook for the near future?
This is difficult to answer and explain in a few words. I was wondering if we could talk by "skype" some another time.

my best regards,
Rosaria Ono

C.2 Transcript of Interview with Dr. Tavares

Dear Mr. Cing Lun Thang,

Regarding your previous email, see my comments below:

*Firstly, do you have, or can you point me to where I might find, recent statistics regarding the number of fires that have occurred in Sao Paulo and Rio de Janeiro (perhaps over the last 10 years?).

I am afraid such type of data is still poor in Brazil. I have collected some data which is presented in one of my papers published at the Fire Safety Journal. I am not sure if you read this paper, but just in case, please find it attached to this email.

* Secondly, would you be able to kindly provide us with information on the current situation with building fire safety codes in Brazil, particularly with respect to the possible transition from prescriptive- to performance-based.

The fire safety codes in Brazil are extremely prescriptive in nature. I cannot see any possible transition from a prescriptive approach it to a performance-based one in a near future. We have been introducing some new methods, such as fire and evacuation modeling simulations for fire safety applcations. Nevertheless, these are almost essentially for academic purposes.

In the attached paper, you can also find some information regarding this issue.

Particularly, I have been trying to introduce evacuation modeling into fire safety and more specifically into crowd safety. It is a challenging process. The aviation field seems to be more open to this type of methodology than the building construction field.

* Lastly, we are interested in the current situation with fire research and fire protection engineering in Brazil: could you update us on the current situation and outlook for the near future?

As I have mentioned previously, I cannot see any transition from prescriptive codes to performance-based ones in the near future (let´s say within the next 5 years or so). Probably the safety culture (and more particularly, what I have been calling "fire safety culture") seems to be a big barrier for this transition for instance. Despite that, some positive efforts are being made due the World Cup of Football (or as in the USA they say Soccer) and the Olympic Games which will take place in Brazil.

I am also sending to you a manuscript published by Professor Rosaria Ono at the Fire Science and Technology. Professor R. Ono is an expert in this field in Brazil and she is one of the pioneers to research fire safety here. So, it might be a good idea to contact her (if you have not done it yet); she is an architect and she has done some work focusing on fire safety codes in Brazil.

Below, there is a link to the website of Professor. Valdir Pignatta; he is an expert on fire safety on structures:

http://www.lmc.ep.usp.br/people/valdir/?page_id=54

I hope this information can help you in somehow. If you need any further information, do not hesitate in contacting me; and if I am able to help you, I will do so.

Regards,

Rodrigo

C.3 Copy of Email Correspondence with Dr. Braga from Prof. Meacham

Hi Brian,
Follow some answers.

- What is the situation with building and fire codes? Are they prescriptive or performance? Are they uniformly enforced? Are there issues, and if so what, and what are the plans to address?

Most of the building codes are county level codes, but, since the fire departments are state departments, the fire codes are state level. Sometimes there are some conflicts, but, in most of the cases, the fire codes surplus the building codes.

The fire and building codes are prescriptive, but, in some particular cases, in special here in the Federal District (we are like DC in US), the can accept a different solution, as long as the builder can prove it is safe. It is really rare.

Each state can have it own code, but, I could say, most of the 27 states follow one of the following codes: Federal District and São Paulo. But, important states like Rio de Janeiro, Minas Gerais and Rio Grande do Sul, follow their own codes. This is a big problem, because some company can build a supermarket in Rio de Janeiro, but can't use the same plan to build in São Paulo. That's why since 2006 there are a lot of discussion and effort to build a national fire code. But, unfortunately, I can't say we are close to it.

- Is there any fire protection engineering in Brazil, particularly for performance-based fire design? If not, why not? What do you see as needed to support PB design for fire in Brazil?

In Brazil there isn't any Fire Protection Engineering graduation or under graduation course. Some universities, like University of Rio Grande do Sul, University of São Paulo and University of Brasilia, there are a lot of discussion about to create a graduation course (master or PhD degree). In 2010 I participated in a discussion at the Engineer Faculty in the University of Rio Grande do Sul about this, and it make me believe they were in the right track to have a Fire Protection Engineering course there.

As you can see, not having anyone with a fire protection degree is the biggest problem to have a PB design in Brazil. Here, most of the designs are made by Civil Engineers and firefighters with a Civil Engineer degree. An important note here: The Firefighter offices in Brazil has a 3 years, full time, undergraduate course with a lot of civil engineer classes.

I believe, and most of the people that I know, believes that is important to have a fire protection engineer course to step up to PB fire codes. But not only that, we need to have fire protection engineer working at the Fire Departments to approve the designs.

- What is the fire safety culture? That is, are the public aware of / concerned with fire safety issues? How do you deal with public education?

I Brazil, fighting fires is about 25% of our Fire Departments work. Most of our job is in EMS, but we have a lot of work doing fire design analysis and building inspection. But that's the case of Brasilia (Federal District), because we are a new city (build from scratch in 1960), with a 6,000 firefighters for a population of 2 million.

But, answering your question, in general the people has not much concern about fire. It is hard to explain why, but I could say that, because of our buildings and house are made of bricks and concrete, including the internal walls, most of our fires stay in the origin compartment, not spreading to the whole building. This gave to the population, in the past years, a false sense of safety. But this is changing. Right now we can star to see a big change in the way the buildings are being constructed, and we might star to see a increase in the number and severity of the fires.

- What is the structure and role of the fire departments? Paid, volunteer, a mix? How well are fire departments resourced?

The fire departments in Brazil are, as I said, a state department. Every state (27) has a paid fire department. But, not all cities have a fire station. That's why some states have a volunteer FD (only two). But on those states, the paid "control" the volunteer one, so I could say they are mix. The average of firefighters per population in Brazil is around 1 for 2,850 people. In Brasilia we have 1 firefighter for 500 people, but you can find states, like Maranhão, with a ration of 1 firefighter for 7,735 people. This number can show you that the FD resource depends a lot with the state. Some, like Brasilia, has helicopters, airplanes, and, even research structure, but others has even problem with protection equipments.

- Do you have a fire reporting system like NFIRS? If so, what type of data do you collect? If not, would it be beneficial to have one? What would be the challenges to implement?

Every fire department has a reporting system, and there is a federal agency that collects the data every year. The problem is, each state collects the data the way they want, and sometimes it is really hard to combine them. To solve this problem, in 2008 all state fire departments created a standard reporting system. This system still been implemented, but I believe it will take more time them it suppose to. The problem to implement is that some states don't like to change their systems to the new one. And, since it is completely voluntary to use this system, they don't have motivation to do so.

I'm still waiting for more information from some friends.
I am attaching a presentation about the Federal District Fire Department, but it includes some information about the Fire Departments in Brazil.

Please, let me know if I didn't answer some question or if you need more information.

Best regards,
George

C.4 Additional Information on Current Fire Codes in Brazil

C.4.1 History of Fire Codes in Brazil

Earliest records of Brazil start from the Portuguese colonization from the 16th to 19th century. On September 7th, 1822, the country declared its independence from Portugal and became a constitutional monarchy through a relatively peaceful process although it remained under Portuguese authority until the "liberal revolt" in 1889. Brazil was known as a democracy between 1946 and 1964 until the military seized power. In 1980, due to increasing economic problems and dwindling civilian support, the military allowed the restoration of democracy (Gerring, Kingstone, Lange, & Sinha, 2011).

One of the famous emperors and a patron of the Military Fire Brigades of Brazil is Emperor Dom Pedro II who founded the first official fire department in Brazil on July 2nd 1856. The primary mission of the Fire Brigade of Rio de Janeiro was to carry out the prevention and fighting fires. As a result of a disastrous fire in February 15th 1880 which destroyed the library in the College of Law, then located in the San Francisco Convent, there was the founding of the Fire Brigade in Sao Paulo.

The fire service in Brazil is militarized. Each state has its own Military Fighting Corps. For example, in Sao Paulo state, the Sao Paulo Firefighters belong to the Sao Paulo State Police. However, cities in Southern Brazil have had volunteer firefighters since the early nineteenth century (Polícia Militar do Estado de São Paulo,).

The fire department continues to be part of the military organization, separated by state. In 1940, the Brazilian Association for Technical Standards (ABNT) was founded. Within this association, there is a committee for Fire Protection (C24) which is located within the fire department (United Nations Environment Programme, 1999). A founding member if the ISO, the ABNT is a standards organization that is responsible for the regulation of building codes in Brazil which includes fire protection (National Institute of Standards and Technology, 2002).

C.4.2 Current Prescriptive Codes and Its Problems

The fire codes in the Brazil are largely prescriptive in nature. Although the national fire codes exist, a general document that lacks details, the regulations differ from state to state (Rodrigo Machado, 2009). Brazil has experienced many great fires that resulted in loss of life and costly damage. However, the history of Brazil's codes shows that Brazil has a very reactive stance towards fire. An observation of reports following major fire disasters follows a pattern which enforces detailed ranges of prescriptive measures to ensure that the incident will never be repeated (Duarte, 2011). However, the adjustment halted without progressing to explore preventive measures that would further develop the fire safety codes.

The Andraus Building is a 31-story, reinforced concrete department store and office located in Sao Paulo. On February 24th 1972, a fire occurred in what was designed as a fire-resistive building. The fire engulfed the entire building about 15 minutes after the fire started and continued with great intensity for four hours. This fire resulted in 16 casualties and 329 injured (Abrams, 1977).

The Joelma Building Fire followed closely. In February 1st 1974, an electrical failure in a window air-conditioning unit ignited the fire in the25-story structure. The building had no lighted exit signs, manual fire alarms, fire detection systems or emergency plans. The fire spread quickly due to the interior finish. In addition, there was no safe exit which resulted in the use of elevators for rescue. The incident ended with the loss of 179 lives (Pires, de Almeida, & Duarte, 2005).

These fires brought the founding of the Department of Civil Defense that is dedicated to study of fire and proposes alternatives for the safety of the population. On the 30th of September 1975, the law no. 684 was published. With the intent to improve fire safety measures such as prevention and extinguishing, this law authorized the government to establish communication with the local authorities in the cities. In terms of fire codes, as a result of the Joelma Building Fire, the Normas Regulamentadoras—NR 23 was defined. The NR 23 is dedicated to fire protection and defines issues such as lining materials for walls and doors, construction of fire-walls, occupants' circulation within the enclosure facilities, protection of the corridors and the emergency exits and use of emergency signage.

The next major fire occurred in 1986 in the 23 story Grande Avenida building in Sao Paulo City. This fire claimed the lives of 17 people and injured 53 people. Once again, existing laws were updated in 1983 where the state law no. 20.811 was established. This law defined several issues such as the use of emergency stairways, fire-walls and fire-doors, emergency routes and so on.

In 1986, Brazil experienced one of its biggest fires in 21-story office building that is the headquarters of the Sao Paulo Power Company (CESP) followed by the founding of the Brazilian Committee of Fire Protection. This committee was responsible for defining several aspects within fire safety, namely development of the fire design, analysis and evaluation of constructive materials resistance performance to fire, methodology for laboratory tests and terminology of fire safety concepts (Rodrigo Machado, 2009).

The Andraus Building and Joelma Building were both reinforced concrete buildings. The fire caused spalling of the exterior walls, joists and columns, exposing reinforcing. Similarly, the exterior walls of Joelma Building experienced spalling. The CESP Buildings were constructed of reinforced concrete framing with ribbed slab floors. The fire resulted in a significant partial collapse of the central core of the CESP building 2(Beitel & Iwankiw). Despite these fires, concrete is assumed to be inherently fire resistive and the majority of Brazilian concrete buildings do not require fire safety conditions with the exception of staircases in new buildings and water supply

As a result, Brazil has seen a relatively rapid increase in the application of steel structures for both high and low buildings. These steel structures are required to meet very specific fire safety conditions and strictly follow the prescriptive codes by the ABNT (Lobo & Wildt, 2003). Examples of these codes would be the NBR-14432 “Fire Resistance Requirements for Building Construction Elements” and the NBR-14323 “Steel Structures Fire Design”. The NBR-14432 is a prescriptive standard for minimum fire resistance time of construction elements. The required elements are to prevent structural collapse making the escape safe for users, reduce damage to neighboring properties and to allow prompt access by the fire brigade when necessary. The NBR 14323 provides a simple method to calculate the fire resistance design for steel structural elements (e Silva & Fakury, 2002).

In order to obtain approval for buildings and renovations, one of the papers needed to be submitted is proof of Fire Department inspection depending on the activity of the building. These activities are organized into five categories: residential, services, industrial, commercial and civic (Angloinfo,). Regulation by which the Fire Department analyzes is still highly prescriptive with the Fire Department staff extremely reluctant to approve performance- based design (Ono, 2011). One factor that challenges the development of fire codes in Brazil is the lack of fire data. Data from 1990 to 2000 show a steady increase in the number of fires (Rodrigo Machado, 2009). Because data is not readily available, it is impossible to determine whether the increase in fires is due to the lack of fire safety measures in the current prescriptive codes.

As a result of investigation of the way fire data was recorded, it was found that every fire department has a reporting system and a federal agency that collects the data every year. The current problem is that these states have no specific method to collect this data and as a result, it is extremely hard to combine all the data. However, in 2008 all state departments created a standard reporting system but because it is completely voluntary to implement this system, most fire departments continue using the old system.

C.4.3 Transition to Performance-Based Fire Safety Codes

As a result of urbanization, "favelas" present major fire risks due to flammability of materials used in construction and the close proximity of the buildings. In addition, the absence of formal street grids makes these areas difficult for fire fighters to reach in an event of a fire. There are frequent reports of fires in the favelas which displaces hundreds of people at a time(Duffy, 2009). As a response to informal housing, many urbanization projects are building low-cost apartment complexes made of cold formed steel and ordinary bricks. The low cost building projects could come as an expense to certain comforts and even safety (Batista & Ghavami, 2005).

On 3rd January, 2002, there was a fire in one of these complexes. The four storied steel framed building "Conjunto Habitacional Juscelino Kubitschek" was built in 1988, in Limeira city (State of Sao Paulo). It constitutes four identical blocks, two by two. Each block has four floors, with eight apartments per floor. These apartments are very simple and measure 44.29 meters squared in total area, and consist of two bedrooms, a living room, kitchen, a bath-room and a small service area. The building has a steel cold formed structure. Although the fire had been developed without any restraint, the fire did not spread to neighboring apartments. Furthermore, the damaged structure presented no risks of global or partial collapse.

Thermal and structural analysis, by using software (SMARTFIRE, Supertempcalc and others) and metallographic tests were performed. It was concluded by metal analysis that steel components were heated up to temperatures below 550℃ for the central column, and around 650°C for the hottest beam. Computational modeling shows "medium" temperatures about 380℃ in central column and 610℃ along beam. Based on these results, and applying simplified structural analysis, it can be observed acceptable safety levels. The aim of the analysis was to study inherent fire in low-cost residential buildings without the traditional application of fire protection (e Silva, Fakury, Rodrigues, & Pannoni, 2006).

In 2008, ABNT approved the first performance based specification for the Brazilian construction industry, the NBR 15.575/2008 which stated that residential buildings up to five stories will be evaluated on the overall performance of the system instead of the quality of each individual part such as the concrete or steel structure (Tanesi et al., 2010; Tanesi, Da Silva, Gomes, & Camarini, 2010).