# Cost Benefits of Steel compared to In-situ Concrete in Sri Lankan Building Construction

**Chandanie H.**
Department of Bulding Economics, University of Moratuwa, Sri Lanka
chandanieqs@yahoo.com

**Kandemulla L**
Department of Bulding Economics, University of Moratuwa, Sri Lanka

**Abstract**

*Ever increasing building construction activities involve high technologies and innovations to overcome the challenges in front of the process. Among the key challenges of building construction, cost of construction is prominent. However the construction industry constantly experiment innovative solutions which may offer favorable cost benefits for building construction. Most of developed countries draw attention on material-wise solution together with better administration and co-ordination within construction environment. Concerns on steel as a cost effective material for construction is one of an ideal example which suggested having the ability to offer better answers for future construction challenges. Steel buildings are designed, fabricated and constructed to meet the needs of the customer and to be cost effective. With steel construction, delays in construction are less, and unexpected costs that often associated in traditional constructions are reduced or eliminated. Properties of steel and vantages of steel construction also have been influenced in erection of steel structures such as skyscrapers, high-rise building and other small buildings in the developed countries. Future adaptability with easy connection systems, minimum waste, long life, reduced disruption at sites, suitability for confined sites are some benefits of using of steel as the main construction material. Eventually, above-mentioned benefits of steel will be afforded indirect cost benefits of steel building construction.*

*The aim of this research is set as to identify the cost benefits of steel building construction in terms of factors of production in Sri Lankan construction industry. In achieving the above aim the method followed comprises of a comprehensive literature survey followed by a questionnaire survey. Data collection was done through the questionnaire survey to gather expertise knowledge and experiences of professionals in the industry. Through the questionnaire, related cost influence factors of production were compared between steel and in-situ concrete construction. Questionnaires were distributed among 44 construction industry professional and received 30 responses. The collected data was analyzed using RII, binomial test and median and approach to two major outcomes. Cost factors were identified which were offered cost beneficial and not cost beneficial separately in steel building construction compared to in-situ concrete building construction. It was found out that labour, material related costs are beneficial factors of steel construction over in-situ construction. In-situ construction is ahead of steel in terms of cost benefits in the areas of land, standards and technologies related cost factors whereas maintenance cost shows no significant difference. Therefore it can be concluded that steel construction offers cost benefits over in-situ construction as labour and material contributes to a higher proportion of project cost.*

***Keywords:*** *Buildings; Cost Benefits, Sri Lanka, Steel Construction,*

## 1.0 Introduction

Building is one of the most important activities in any economy and it consumes a large amount of national resources for the construction and maintenance of buildings (Stone, 1983). Building construction needs ordered and planned assembly of materials, which are assembled at outdoors through a large number of diverse constructions. Therefore, Building construction is a complex process with its unique characteristics (Mehta, Scarborough, & Armpriest, 2008).
The proper selection of materials can influence the cost of construction, maintenance cost, durability and its appearance. Materials, which are used to construct structural elements of the building, are in wide varieties. Woods, concrete and steel are commonly used construction materials in many parts of the world because of their inherent properties of construction (Mrema, Gumbe, Ghepete, & Agullo, 2011).

Steel is increasingly becoming a more popular material for building construction in recent years and uses as a major construction material in building construction for most of structural elements in buildings. Abesuriya (2007) stated "the common structural form of a multi-story steel building consists of steel H sections as columns, wide flange sections or I sections as beams, and concrete floors" (p.22). In addition, Abesuriya (2007) mentioned that walls could be block, brick or glass curtain walls for facades of buildings. Therefore, steel buildings are normally constructed as composite buildings, with the involvement of number of various construction materials (Panchal, 2010).

Steel buildings are designed, fabricated and constructed to meet the needs of the customer and to be cost effective. With steel building construction, delays in construction are less, and unexpected costs that often associated in traditional constructions are reduced or eliminated (Noton, 2010).

There are some landmark steel buildings in the world, such as the Empire State Building, which is the tallest of buildings in New York (Post World Trade Centre). Its height is 381m and is currently functioning as an office building. Contractor have been managed to build this steel framed structure in a record time (thirteen months). The Aon Centre building is the third tallest among all-steel buildings in the world which is located at Chicago. There are some more to be given as examples for popular use of steel material as, John Hancock Centre Chicago high-rise office building and Minsheng Bank building China with 68 floors (ITP Business Publish, 2010) being some good example.

Properties of steel and vantages of steel composite construction also have been influenced in erection of steel composite structures such as skyscrapers, high-rise building and other small buildings in the developed countries. Steel Framing Alliance (2013) reported that steel is considered as a green material because of its recyclable ability. According Abesuriya (2007) Report of Annual Transaction of Institute of Engineers Sri Lanka (IESL) the construction time can be reduced with pre-fabrication and erection method of steel construction and higher quality can be maintained. Future adaptability with easy connection systems, minimum waste, long life, reduced disruption at sites, suitability for confined sites are some benefits of using of steel as the main construction material in steel construction.

As explained, unlike Sri Lanka, steel composite building constructions are famous in intentional construction industry. Because of that, steel composite construction benefits as a material and in construction operation at the site. Eventually, above-mentioned benefits of steel building construction will be afforded indirect cost benefits in composite steel building construction.

### 1.2 Problem Statement

The pre-fabricated steel or turnkey type buildings will be the future in the world construction industry with the ever-increasing building materials cost and the time consuming factor. In addition, the strength and durability of steel as a construction material is well known and these qualities also help reducing the cost of steel buildings by ensuring the longevity and sustainability of such structures (Tuknov, 2012).

However, there are less numbers of steel building constructions in Sri Lankan construction industry while steel building constructions are well known worldwide due to its above-mentioned benefits. Therefore, it is important and vital study whether steel building construction is economical in Sri Lankan construction industry.

Cost effectiveness of steel building construction need to be considered based on land, labour, capital and entrepreneurship that are being the factors of production in construction industry (Colaner, 2008). The factors of production will define the total cost of the products. Therefore, the cost benefits present under these categories would be leading steel into a conclusion that steel as a cost beneficial material in the construction. With such background, the research considers it as an important study to do some scientific investigation to check steel building constructions as a cost beneficial solution for Sri Lankan building construction.

### 1.3 Aim

Based on the background study, the aim of this research is to identify the cost benefits of steel building construction in terms of factors of production in Sri Lankan construction industry.

### 1.4 Objectives

- Explore different cost aspects under the four factors of production in construction of building.
- Identification of factors affecting to the cost, related to factors of production in building construction.
- Compare the cost aspects of steel building construction with in-situ concrete construction.
- Identify steps to reduce the construction cost through usage of steel in building construction.

## 2.0 Literature Review

### 2.1 Introduction to Steel Building Construction

Composite steel construction are falling into two categorize as "composite steel and concrete building construction", and "composite steel building construction". Composite steel and concrete building construction is a type of steel building construction done with structural members who formed bonding concrete components to steel member (Ellobody & young, 2010). Whereas, composite steel building construction considers steel as the main construction material and some elements of the building are constructed out of different material such as brick or block masonry for walls, precast concrete units for slabs and in-situ concrete for foundations (Abesinghe, 2007). This research "benefits of steel composite building construction" explores the benefits of composite steel building construction (hereinafter the term "steel building" is used for "composite steel building" construction).

The structural frame of a steel building is constructed by assembling prefabricated steel components at site. Structural steel sections such as I beams, H sections , angle irons, circular and square hollow sections etc, have been used widely in the global building construction industry (Abysinghe, 2007). A unique feature of steel building structure is that the assembly details. Details of the connections between steel components are not prepared by architecture or structural engineer, but done either by independent detailing company or by an in-house outfit of a steel fabricator (Mehta, Scarborough & Armpriest, 2010). Therefore with such unique characteristics it could be hypothesized that steel building construction would have provides different and strong benefits to the construction project.

### 2.2 Structural framing construction process

Nunnally (2007) stated that structural framing construction is the most significant part of the steel building construction. Therefore structural framing construction process is a well-established planning assembly process with the several distinct stages. They are identified in steel building constructions process given as in Figure 1.


**Figure 1:**
**Steel building frame construction process**
Source: (Mehta, Scarborough & Armpriest, 2010)

Preparation the preliminary layout involves careful integration of structural consideration with several nonstructural considerations, such as HVAC, the building envelop, fire resistance, interior finishes, aesthetic, and cost. Unlike masonry and site cast concrete construction, structural steel components are brought to the site in a prefabricated and finished state, ready for erection and assembly. Detailing should be done in the most economical manner and in a way which is best suited for the erection, scheduling, and the condition of the site. Fabrication of steel components included cutting plates and angles to the required size, punching plates and angles, drilling holes of the required diameters and spacing. The erection of the structural steel frame at the site may be performed by the fabricator or by a separate erection company. In most cases, the general contractor will seek separate bids for fabrication and erection. Fabricator and erector can be selected on the basis of a competitive bid (Mehta, Scarborough & Armpriest, 2010; Nunnally, 2007).

### 2.3 Relationship between Steel and In-situ Construction Cost and Factors of Production

According to economics theories, factors of production are the inputs of a product or a service namely land, labour, capital, and entrepreneurship. These factors determine the final cost of a product or a service in any industry (Colander, 2008). In the construction industry, cost of each factors of production can be illustrated with regard to different aspects in different steps involve in a process.

Land cost is comprised the cost of all natural resource which are used in production, including non renewable and renewable resource and land itself. Labour cost, includes cost of all working people ranging from the unskilled worker to the most highly trained workers. Capital cost includes the cost of all the manufactured inputs for the construction process such as machinery, material together with indirect cost. Entrepreneurs are individuals who are prepared to take risks and mange all above three factors of production inputs (Cooke, 1996).

The construction cost of building may be varied according to method of construction. The identical factors of production are subjected to cost comparison with the cost significant factors in the building construction process. This cost comparison in relation to steel and in-situ is based on Standard Method of Measurement (SMM7) work sections for the buildings. Building construction works are classified in element wise in the SMM7 as earth work, foundation, column/beam, slabs, roof, walls, finishes and service installation.

### 2.3.1 Land

Land plays a significant role in building construction that determining the ultimate cost of the construction output. Figure 2 shows the cost accumulating factors in building construction process with regard to land.

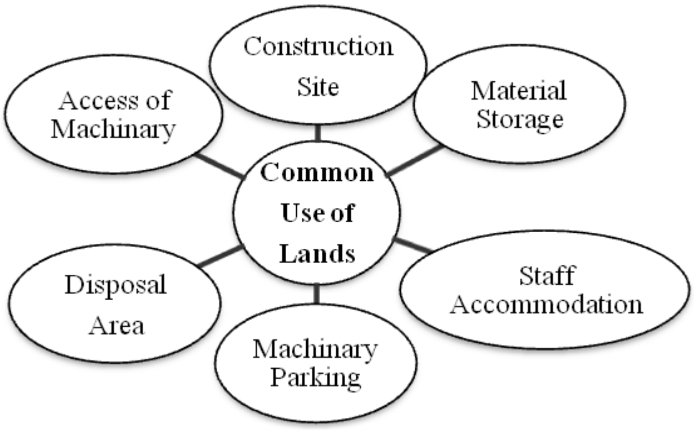


**Figure 2: Common use of land with regard to construction project**
Source: (Harvey and Jowsey, 2004)

Above factors are influencing the ultimate cost of the construction output. The final product cost will be changed according to the type of construction (Stone, 1983). Therefore, construction methods (whether its steel building construction or in-situ concrete building construction) would be having different land cost influences due to above factors.

Major cost adding and deducting factors related to land in the steel building construction process is recognized in the Figure 3. The factors of land are identified comparatively to the in-situ concrete construction process. Cost "Deducting" factors are represent cost saving and "Adding" factors are the additional cost of the steel building construction process.

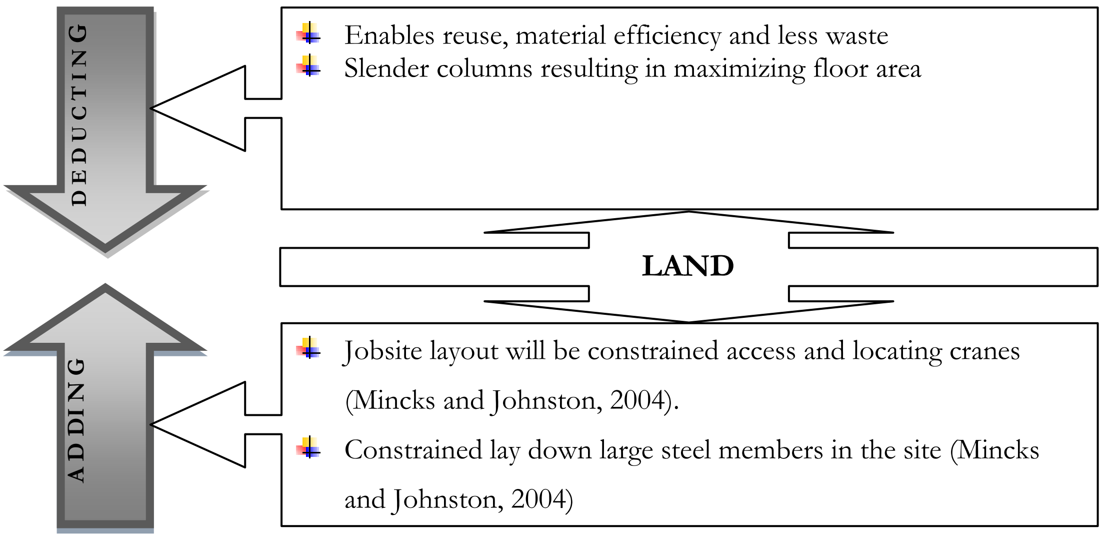


**Figure 3: Cost components comparison of land**

### 2.3.2 Labour

"Labour" is a highly cost significant factor in a construction project (Briscoe, 1988). Popescu, Phaobunjong and Ovararin (2003) stated that " the labour cost component of a construction project often ranges from 30% to 50%, and can be as higher as 60% of the overall project cost"(p108). Pricing labour is one of the most difficult tasks in cost estimate, as pricing labour involves high number of variables to be in concern. It is also a subjective factor in cost estimating unlike pricing materials or equipment (Briscoe, 1988). Further, there is a high involvement of labour gangs which are specialized in performing in different construction trades. Each group under any category would be having different cost influences to the project. Major cost adding and deducting factors of labour in the steel building construction process is recognized in the Figure 4. The factors of labour are identified comparatively to the in-situ concrete construction process.

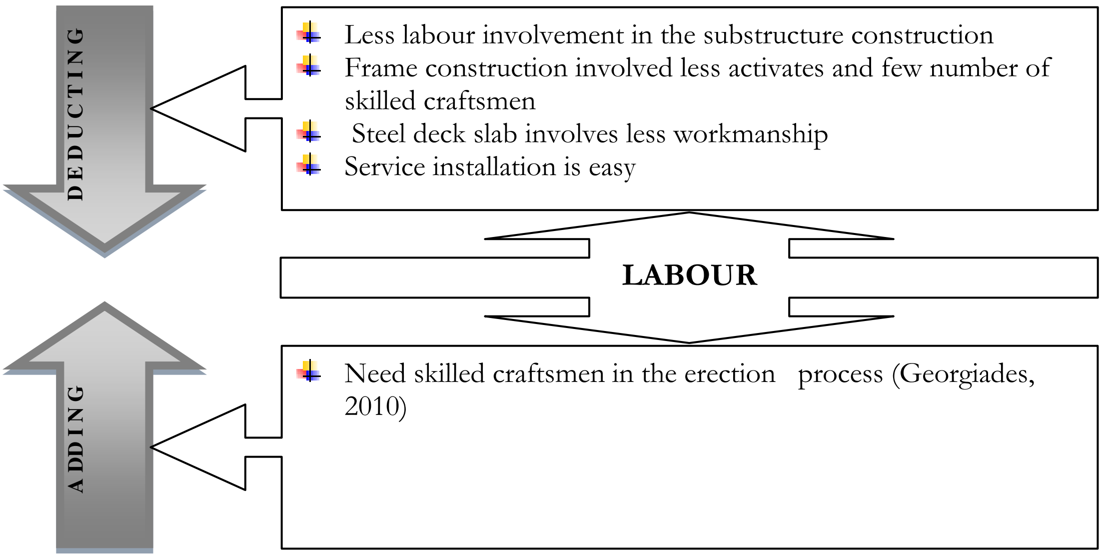


**Figure 4: Cost components comparison of labour**

### 2.3.3 Capital

There are three major categories of capital good in the construction industry as structures and overhead, equipment and inventories of inputs. Structures and overhead cover construction firms, accommodation buildings, job site personals etc. Equipment is the durable goods like automobiles, tools and computers and capital are the capital items inventories of inputs such as material use for the construction. Frequently firm use their own capital goods but some capital goods have to be rented in externally (Nordhaus, 2005).

***Cost of materials***

Material is a high cost significant input of the construction industry. Material cost related attributes in each construction technologies are given in Table 1.

**Table 1: Material cost accumulation components**

| Element | Steel building | In-situ concrete |
|---|---|---|
| Foundation (eg:-shallow foundation) | -Concrete, reinforcement, formwork and Gunny bags<br>-Transportation and Storage | -Concrete, reinforcement, Formwork and Gunny bags<br>-Transportation and Storage material |
| Beams and Columns | -Steel members, nut and bolts, angles, plates and stabilizers<br>-Detailing steel members<br>-Fabrication members<br>-Handling in each stages<br>-Transportation and Storage material | -Concrete, Reinforcement, Formwork and Gunny bags<br>-Transportation and Storage material |

| Element | Steel building | In-situ concrete |
|---|---|---|
| Slab systems | -Steel decking, concrete, reinforcement<br>-Transportation and Storage material | -Concrete, Reinforcement, Formwork and Gunny bags<br>-Transportation and Storage material |

***Cost of equipments***

Equipment cost rank second after labour costs in construction due to their high involvement in modern construction projects and the unpredictable nature of production of a construction project (Stone, 1983). Equipment can be acquired through three methods purchasing, renting or leasing (Gransberg, Popescu & Rayan, 2006). Machineries which are used in steel and in-situ building construction process are given separately in the below Table 2.

**Table 2: Plants and equipments use in the construction**

| Element | Steel building | In-situ concrete |
|---|---|---|
| Foundation (eg:- shallow foundation) | -Poker vibrator<br>-Pump car | -Poker vibrator<br>-Pump car |
| Beams and Columns | -Tower crane, and man lifts<br>-Mobile crane<br>-Welding plants and generators | -Poker vibrator<br>-Tower crane<br>-Pump car |
| Slab systems | -Tower crane and, man lifts<br>-Mobile crane<br>-Welding plants, and generators | -Poker vibrator<br>-Tower crane<br>-Pump car |

***Structures and overhead***

Structures and overhead are the indirect cost for the construction work, which is not a directly involving cost component to the construction work at the site. Firm and the temporary site accommodation facilities are considered as structure cost. Rental, taxes and running cost are major cost element of the structures. Overhead cost includes mobilization cost, job site personal cost and cost for the site utilities (Smith & Jaggar, 2007). Cost attributes of structure and overhead of the two types of construction are presented in Table 3 (Steel frame vs. In-situ concrete building).

**Table 3: Cost components of structures and overhead**

| Construction stage | Steel building | In-situ concrete |
|---|---|---|
| Bonds | -Bonds, insurance, permits<br>-Taxes required in the contract general conditions | -Bonds, insurance, permits<br>-Taxes required in the contract general conditions |
| Mobilization | -Field buildings<br>-Horizontal structures (roads, parking, fences, and gates) | -Field buildings<br>-Horizontal structures (roads, parking, fences, and gates) |
| Job site personals | -Wages and fringe benefits<br>-Project related travel expenses | -Wages and fringe benefits<br>-Project related travel expenses |
| Construction period | -General use equipment (eg:- crane, hoist)<br>-Site utilities in job duration<br>-Whether protection of completed works or works in progress<br>-Protective aids and safety measures for workers | -General use equipment (eg:- crane, hoist)<br>-Site utilities in job duration<br>-Protective aids and safety measures for workers |

Major cost adding and deducting factors of capital in the steel building construction process is recognized in the Figure 5.

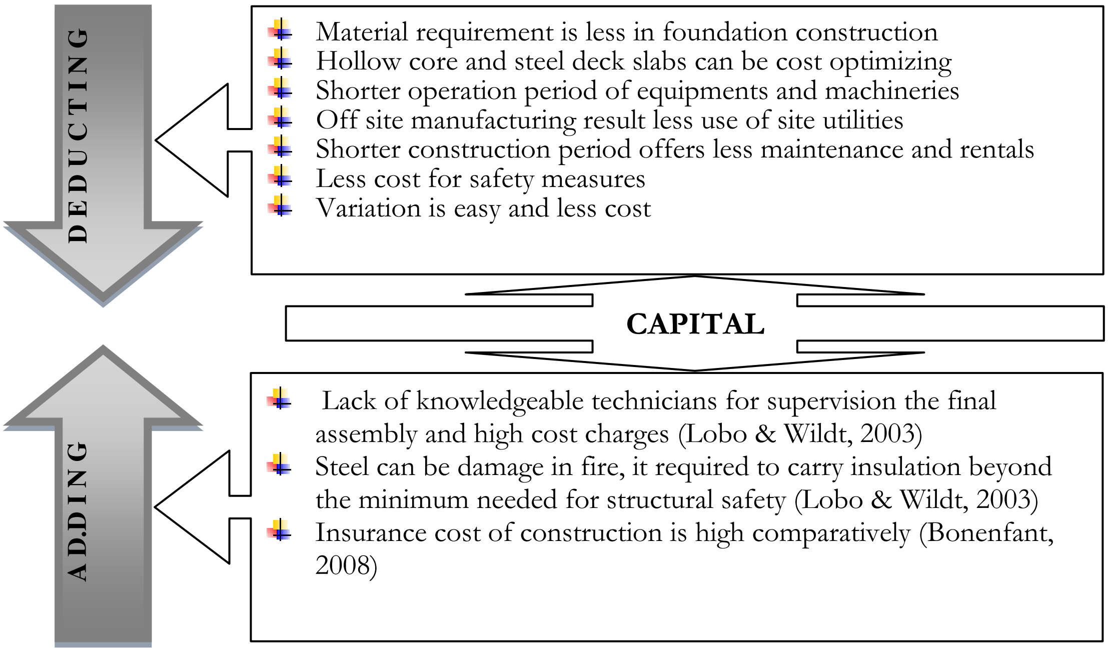


**Figure 5: Cost components comparison of capital**

The factors of capital are identified comparatively to the in-situ concrete construction process.

### 2.3.4 Entrepreneurship

Construction entrepreneurs are significantly involving various ways in the construction industry and take many directions and field into construction such as sustainable construction entrepreneurs or by working more on the design side as an architect entrepreneur (Burke, 2011).

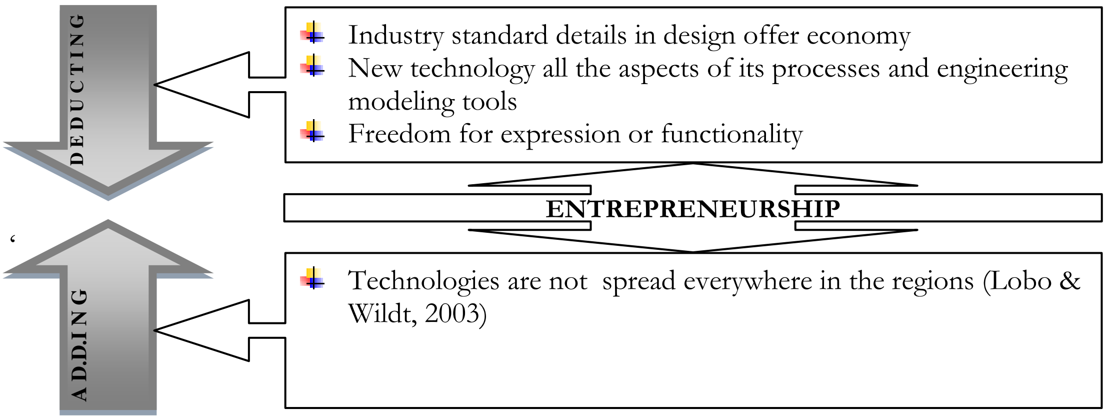


**Figure 6: Cost components comparison of entrepreneurship**

Burke (2011) and Hedley (2013) stated that the construction industry entrepreneurs are involving several areas. They are suppliers of innovations based on various technologies to the construction industry. Construction entrepreneurs innovates successful experimentation, development and introduction of new products, processes, combinations, services or organizational forms. Further entrepreneurs have the ability to be scaled up to change or replace current practices in the sector which results in reduced deterioration of the human environment and natural resources while at the same time retained or improved economic competitiveness. Major cost adding and deducting factors of entrepreneurship in the steel building construction process is recognized in the Figure 6. These factors of entrepreneurship are identified comparatively to the in-situ concrete construction process.

### 2.4 Best Practices to Reduce Steel Building Construction Costs

There are many potential economies to using a structural steel frame. Economy begins with an efficient design and layout by the structural engineer, and can be maintained or increased during fabrication and erection by careful coordination and communication by all parties. Site layout and construction sequencing will influence equipment requirements and cost, as well as the speed of erection. The cost reduction factors are discussed under the design stage and construction stage below.

***Design stage***

In construction management, design-build project delivery methods, the steel contractor may be in a position to provide early input into the design, which may lead to design that is more economical. The quality of the contract documents has a significant impact on the ability of the estimator to determine precisely what is required for the project. Incomplete or poor detailed planes require the steel contractor's estimator to guess at the designer's intentions. To be protected from risk of future modifications or (bulletins), the estimator will naturally increase the price (Mrozowski, Syal & Kakakehe, 1999).

***Construction stage***

Following list of cost-saving measures can be practiced in the steel building construction process. These measures provide more efficient construction environment in the steel building construction process.

The specification of special coatings will add significant cost to the project. Preparation of the surface, painting, handling, and paint touch-up, are all increased by the use of special coatings. Where architecturally exposed steel is to be used on the project, these coating may not be avoidable. However, fabricators should be consulted during preparation of specifications to determine the appropriate coatings and their ability to apply them. When steel is to be completely enclosed, painting may not even be necessary (Mrozowski, Syal & Kakakehe, 1999).Site layout and configuration, as well as construction sequencing, are important elements in establishing the type of equipment and the time required to erect the structure. Close coordination by the erector, fabricator, and contractor in project planning for construction can increase the efficiency of the erection crew and consequently reduce erection costs. Avoid connections which require extensive field welding when possible. When the design is such that field welding is necessary, connections should be designed to avoid awkward or overhead welding angles. Steel shapes, which have cost premiums, should be avoided when possible. Some structural shapes, such as bent and tees require fabrication to achieve the shape. The use of angles instead of bent plates may save project costs (Mincks & Johnston 2004).

## 3.0 Research Methodology

This research falls in to post positivism paradigm philosophically. Therefore survey approach was most suitable to achieve the research objects. The simple random sampling method was adopted to select sample from the population. The professionals who have experienced in steel building and in-situ building construction practices were the population of the research. These professionals should have knowledge and understanding in steel building and in-situ building construction practices and cost aspects of processes. Therefore the professional quantity surveyors and engineers were belongs to the population of this research. The questionnaire survey was implemented with thirty professionals using a respond scale.

The collected data was analyzed using descriptive statistics analysis methods, relative important index (RII), binomial test and median. MS-Excel computer base software was used to calculate the RII value. This has been identified as a data analysis technique in order to rank the factors and identify the most significant factors. The binomial test shall be used at the circumstance of dealing with nominal categorical data and the population may be classified only into two categories. If the probability of obtaining an element is being "p" probability of second sample shall be "1-p" (q) in this type of data distribution. The null hypothesis ($H_0$) shall be rejected if calculated probability is small than $\alpha = 0.05$.
Median is the best method to ordinal data analysis which is concern on distribution of data set. The data were to be presented in graphical manner using Microsoft offices excel.

## 4.0 Research Findings and Discussion

### 4.1 Respondents Details

Questionnaires were distributed among professional quantity surveyors and engineers who engaged in building construction works, where they were randomly selected from consultancy and contracting organizations. Response rate was 68%. According to the responses categorization consultants and contractors organizations are represented respectively 33% and 67%. Among them 27% were Engineers and Quantity surveyors were 73%.

## 4.2 Identification of Cost Benefits of Steel Building Construction

It is a query whether the cost benefits exist in steel building construction in the Sri Lankan construction industry. Among the collected questionnaires 87% of them were responded as steel building construction is cost beneficial material in building construction and 13% responses as in-situ concrete building construction is cost beneficial. Mover over the collected data from this section shall be tested for the population using binomial test. Sample probability of cost benefits of steel is 87%. According to sample probability steel building construction can be considered as cost beneficial as it is more than 50%, which is the critical value. Even though collected data set should be tested for population, where Binomial test can be applied because which is nominal categorical data analyze method.

## 4.5 Comparison of Importance of Identified Cost Factors in Steel Building Construction Compared to In-situ Concrete Building Construction

Respondents were given their responses comparing each cost factors (CFs) and marked in the response scale of the questionnaire provided. RII values of 23 CFs for steel (X) and in-situ (Y) building construction were calculated using the collected responses. Thereafter, the cost factors are ranked base on RII value difference (X-Y) as given in Table 4.

**Table 4: Respondents' relative importance index (RII)**

| No | Cost Factors (CFs) | RII | | | Rank |
|---|---|---|---|---|---|
| | | Steel (X) | In-situ (Y) | Deference (X-Y) | |
| 1 | Labour cost involve in the substructure construction | 4 | 37 | **-33** | 2 |
| 2 | Labor cost involve for the frame construction such as beam, columns and satire ways | 7 | 35 | **-28** | 3 |
| 3 | Labor cost involve of slab construction process | 11 | 33 | **-22** | 6 |
| 4 | Labour cost involve for the service installation | 4 | 22 | **-18** | 7 |
| 5 | Material cost of the foundation construction process | 9 | 31 | **-23** | 5 |
| 6 | Material cost for frame construction process (eg:- column and beams) | 34 | 8 | **26** | 21 |
| 7 | Material cost for slabs construction process | 10 | 25 | **-15** | 8 |
| 8 | Operational cost for equipments and machineries in the construction | 16 | 21 | **-5** | 12 |
| 9 | Cost of site utilities in the construction period | 10 | 24 | **-14** | 9 |
| 10 | Maintenance cost and rentals of site offices and other temporary buildings | 7 | 33 | **-26** | 4 |
| 11 | Cost for consideration of safety measures in the site construction process | 17 | 11 | **6** | 17 |
| 12 | Cost for provision of changes and variation in the construction process | 10 | 21 | **-11** | 10 |
| 13 | Cost for providing insurance for the construction works | 16 | 11 | **5** | 15 |
| 14 | Cost allocation for price escalation | 10 | 19 | **-9** | 11 |
| 15 | Cost allocation for risk in the construction | 27 | 9 | **17** | 19 |
| 16 | Cost for finding the industry standard details in design | 19 | 15 | **5** | 14 |
| 17 | Cost for technological aspects of its processes and engineering modeling tools | 25 | 11 | **14** | 18 |

| | | | | | |
|---|---|---|---|---|---|
| 18 | Cost for expression functionality and aesthetic of design | 14 | 15 | **-1** | 13 |
| 19 | Cost for find available technologies in the regions | 32 | 4 | **28** | 23 |
| 20 | Land cost for access and handling heavy machineries | 13 | 7 | **6** | 16 |
| 21 | Land cost for the material storage and lay down in the site lay out | 27 | 6 | **21** | 20 |
| 22 | Cost of maintenance the building | 29 | 3 | **26** | 22 |
| 23 | Cost of demolition and removing debris | 4 | 45 | **-41** | 1 |

Sum of RII (X-Y) is calculated deducting RII value of steel (X) from in-situ (Y). Factors which have high cost for in-situ concrete building construction they become high negative RII values, likewise factors which have high cost for steel building construction, they become large positive RII values as shown Table 4.

### 4.5.1 RII analysis

Relative importance index (RII) was calculated for each cost factor in the section separately for steel building construction (X) and in-situ concrete building construction (Y) in the Table 4. These RII values shall be plotted to acquire following Figure 7 against rank of RII value difference.

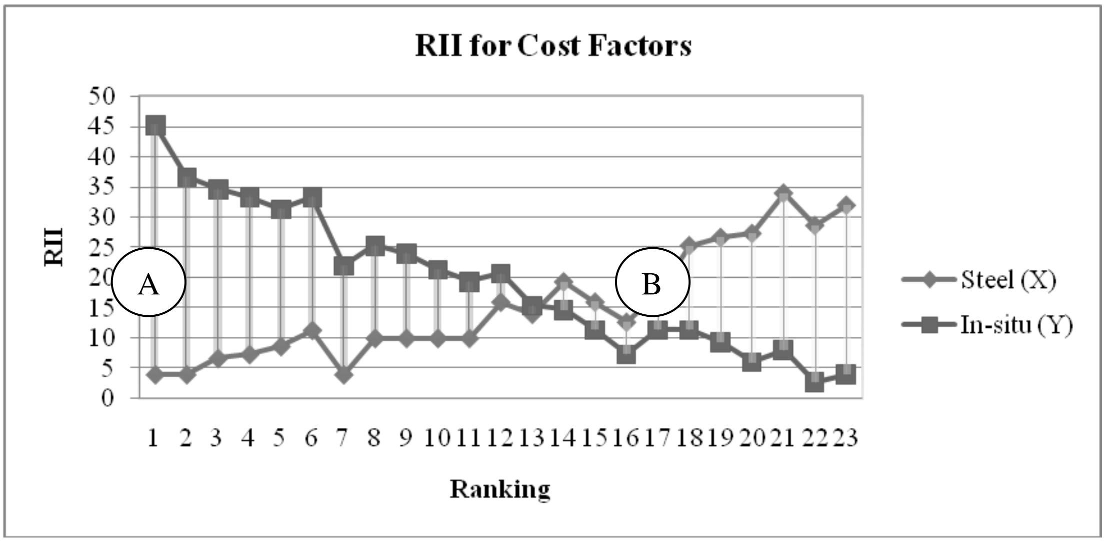


**Figure 7: Steel (X) and in-situ (Y) RII values for cost factors**

Blue and Brown colored lines are representing respectively RII values of steel and in-situ building construction against ranked cost factors. Green colored hatch area (A) is represented that RII value of in-situ is larger than steel and yellow (B) colored hatch is presented that RII value of steel is larger than in-situ. According to the Figure 7 green colored hatched area is larger than yellow colored area (A>B).

RII value is representing comparative cost of each factor given at Table 4. If RII value increases for a particular side comparative cost of a CF will be increased. The first (1) ranked CF which is demolition and removing debris has less RII value for steel building construction side compared to in-situ building construction side according to Figure 7. Therefore this factor having high cost for in-situ building construction compared to steel building construction.
RII value of steel building construction factors are regularly increasing according to blue color line in Figure 7. However, it is not exceeding the brown colored line up to 13th ranked CF which is functionality and aesthetic of design. After that CFs have greater cost for steel compared to in-situ building construction.

### 4.5.2 Construction cost factors analysis by median

The middle value of data distribution will be taken as median when data set established in ascending or descending order. Here thirty (30) respondents have been considered for analysis. According to the number of respondents, median can be taken as the 15.5 position of the data set however that position cannot be interpreted. Therefore response weightage value is taken relevant to 15th and 16th (fifteen and sixteen) positions as particular median of each CF. Medians were calculated using MS office excel computer base software.

***Median analysis for labour related cost factors***

Labour intensive cost factors are separately considered their responses Table 5 with their median position by highlighting. Microsoft Excel spread sheet was used to represent the responses in Table 5. Conditional formatting was emphasized and visualized highlighting median position for each question.

**Table 5: Labor related cost factors**

| No | Cost Factors (CFs) | Steel | | | | | In-Situ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Very High Cost | High Cost | Moderate Cost | Low Cost | Very Low Cost | Not Consider: | Very Low Cost | Low Cost | Moderate Cost | High Cost | Very High Cost |
| 1 | Labour cost involve in the substructure construction | | | | 2 | 2 | 3 | 5 | 9 | 6 | 1 | 2 |
| 2 | Labor cost involve for the frame construction | | | | 3 | 4 | 3 | 4 | 6 | 6 | 2 | 2 |
| 3 | Labor cost involve of slab construction process | | | 2 | 5 | 1 | | 4 | 12 | 3 | 2 | 1 |
| 4 | Labour cost involve for the service installation | | | | 1 | 4 | 6 | 9 | 6 | 4 | | |

It is seemed that all the labour related CFs are costly in in-situ concrete building construction compared to steel building construction. The first factor, labour cost involvement in the substructure construction is costly for in-situ building construction according to the median position in Table 5. The second CF is the labour cost involves for the building frame construction which also have lower amount of high cost for in-situ building construction compared with steel building construction. Labour cost for slab construction and service installation are again costly in in-situ concrete building construction according to Table 5.

***Median analysis for material and plant related cost factors***

Material and plant incur high cost in building construction. Therefore the cost belongs to material and plants have been denoted under four CFs (Table 6) which may significant cost differences in steel and in-situ building construction process. Steel construction process is attentively distinguished and compared in terms of material and plant related cost factors with in-situ concrete building construction in the Table 6.

**Table 6: Material and plant related cost factors**

| No | Cost Factors (CFs) | Steel | | | | | In-Situ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Very High Cost | High Cost | Moderate Cost | Low Cost | Very Low Cost | Not Consider: | Very Low Cost | Low Cost | Moderate Cost | High Cost | Very High Cost |
| 1 | Material cost of the foundation construction | | | 2 | 3 | 1 | | 9 | 11 | 2 | | 2 |
| 2 | Material cost for frame construction process | 1 | 4 | 4 | 5 | 8 | | 4 | 4 | | | |
| 3 | Material cost for slabs construction process | | | 1 | 4 | 4 | 4 | 3 | 10 | 2 | 1 | 1 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | Operational cost for equipments/ machineries in the construction | | | 2 | 6 | 6 | 1 | 7 | 4 | 1 | 2 | 1 |

Material cost of the foundation construction has two median positions shown as Table 6. However both median indicates that in-situ building construction have very low to low amount of high cost for this CF compared to steel building construction. The second (2nd) CF material cost for frame construction in the Table 6 steel side has high rate of responding. Furthermore its median position located in the steel side. Therefore steel have very low amount of high cost compared to in-situ building construction.

Material cost for slab construction again little bit more in in-situ building construction compared to steel building construction. Final CF, operational cost for equipments and machineries of Table 6 is appeared multiple medians such as "not considerable cost" and "very low cost". However exact median should be located in between 15th and 16th position of data distribution therefore it should be costly even marginally for in-situ building construction compared to steel building construction.

***Median analysis for site utilities and overhead related cost factors***

Incurred cost due to construction utilities and overhead have been considered for comparison between steel building constructions with in-situ concrete building construction in the industry. Median values of each CF have been shown in Table 7 below.

**Table 7: Site utilities and overhead related cost factors**

| No | Cost Factors (CFs) | Steel | | | | | | In-Situ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Very High Cost | High Cost | Moderate Cost | Low Cost | Very Low Cost | Not Consider: | Very Low Cost | Low Cost | Moderate Cost | High Cost | Very High Cost |
| 1 | Cost of site utilities in the construction period | | | | 6 | 3 | 3 | 6 | 7 | 4 | 1 | |
| 2 | Maintenance cost and rentals of site offices and other temporary buildings | | | | 4 | 3 | 5 | 1 | 6 | 8 | 2 | 1 |
| 3 | Cost for consideration of safety measures in the site construction process | | | 2 | 6 | 8 | 3 | 5 | 6 | | | |
| 4 | Cost for provision of changes and variation in the construction process | | | 1 | 4 | 4 | 3 | 8 | 6 | 4 | | |
| 5 | Cost for providing insurance for the construction works | | | 1 | 8 | 5 | 4 | 7 | 5 | | | |
| 6 | Cost allocation for price escalation | | | 1 | 5 | 2 | 6 | 9 | 3 | 2 | 2 | |
| 7 | Cost allocation for risk in the construction | 1 | 1 | 4 | 7 | 5 | 2 | 6 | 4 | | | |

Site utilities, maintenance of temporary building, provision of changes and cost allocation for price escalation named CFs (1st, 2nd, 4th, and 6th) have median at the side of in-situ as Table 7 therefore these CFs are costly for in-situ building construction compared to steel building construction. Furthermore there is trend of responses towards right side furthermore most respondents have been determined that this CFs are costly in in-situ concrete building construction compared to steel building construction. However steel building constructions is costly for safety measures and consideration of risk in the construction (3rd, and 7th CFs) with compared to in-situ building construction. Cost for providing insurance for the construction works, neutral response is gained by the median analysis according to result this CF will not affect the method of construction.

***Median analysis for standards and technologies related cost factors***

Standards and technologies are essential for most of the areas of building construction. Table 8 represents the standards and technologies related cost factors of building construction as well as the relevant responses of steel and in-situ building construction process. The highlighted values are the median/medians of each CFs.

**Table 8: Standards and technologies related cost factors**

| No | Cost Factors (CFs) | Steel | | | | | | In-Situ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Very High Cost | High Cost | Moderate Cost | Low Cost | Very Low Cost | Not Consider: | Very Low Cost | Low Cost | Moderate Cost | High Cost | Very High Cost |
| 1 | Cost for finding the industry standard details in design | | 1 | 2 | 7 | 5 | 1 | 6 | 8 | | | |
| 2 | Cost for technological aspects of its processes and engineering modeling tools | | | 5 | 10 | 3 | 1 | 5 | 6 | | | |
| 3 | Cost for expression functionality and aesthetic of design | | | 2 | 6 | 3 | 2 | 12 | 4 | 1 | | |
| 4 | Cost for find available technologies in the regions | | | 6 | 11 | 8 | 2 | 1 | 1 | 1 | | |

Cost for finding the industry standard and details in design have multiple median according to Table 8. In accordance with, median should be in between "very low cost" or "not considerable cost". However this particular position is side of steel according to the median, therefore first CF is costly in steel building by a construction from least amount compared to in-situ concrete building construction. The next CF which is cost for technological aspects of its process and engineering modeling tools also has multiple medians in Table 8. However it is costly in steel building construction compared to in-situ building construction. Cost for expression functionality and aesthetic is costly in in-situ building construction compared to steel building construction. More responses of final CF in the Table 8 trend to side of steel building construction likewise its median also side of steel. Then the CF can be considered as costly in steel building construction compared to in-situ building construction.

***Median analysis land related cost factors***

Land related cost factors shall be listed out as following Table 9. Furthermore comparative responses can be seen in steel and in-situ building construction techniques. Land cost for handling materials and heavy machineries shall be costly in steel construction. Furthermore, most of professionals' responses are side of steel. Then above CFs are costly in steel building construction compared to in-situ building construction process.

**Table 9: Land related cost factors**

| No | Cost Factors (CFs) | Steel | | | | | | In-Situ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Very High Cost | High Cost | Moderate Cost | Low Cost | Very Low Cost | Not Consider: | Very Low Cost | Low Cost | Moderate Cost | High Cost | Very High Cost |
| 1 | Land cost for access and handling heavy machineries | | | 1 | 2 | 13 | 6 | 5 | 3 | | | |
| 2 | Land cost for the material storage and lay down in the site lay out | | | 4 | 7 | 15 | | 1 | 1 | 2 | | |

***Median analysis of cost factors after construction***

The most significant cost factors which may affect to the life cycle cost of construction have been analyzed in Table 10 below.

**Table 10: Cost factors after construction**

| No | Cost Factors (CFs) | Steel | | | | | | In-Situ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Very High Cost | High Cost | Moderate Cost | Low Cost | Very Low Cost | Not Consider: | Very Low Cost | Low Cost | Moderate Cost | High Cost | Very High Cost |
| 1 | Cost of maintenance the building | 1 | 2 | 3 | 5 | 11 | 4 | 4 | | | | |
| 2 | Cost of demolition and removing debris | | | | 1 | 4 | | 4 | 8 | 6 | 5 | 2 |

Building maintenance is essential for effectively functioning the building throughout its life time. Further it's incurring considerable cost where building owner constantly expected to minimize within the life time of the building. However according to median steel is costly for maintenance of the building representing Table 10.

Demolition and removing debris are difficult and costly at the in-situ construction according to median analysis. More over most responses are side of in-situ for demolition therefore the above statement is further substantiated.

### 4.6 Reducing Cost of Steel Building Construction

Accordingly above analysis, it has identified that there are factors which have comparatively high costs in steel construction. In order to minimize such costs, following factors are introduced.

**Table 11: Factors reduce cost of steel building construction**

| No | Factors | Importance | | | | | Count | RII | Ranking |
|---|---|---|---|---|---|---|---|---|---|
| | | Very Low | Low | Moderate | High | Very High | | | |
| 1 | Avoid connections which require extensive field welding when possible | 0 | 0 | 11 | 13 | 6 | 30 | **76.67** | 1 |
| 2 | The use of repetitive members of the same length and size will allow for easier shop drawing development | 0 | 2 | 11 | 13 | 4 | 30 | **72.67** | 2 |
| 3 | Close co-ordination by the erector, fabricator, and contractor in project planning for construction | 0 | 3 | 12 | 11 | 4 | 30 | **70.67** | 3 |
| 4 | Design-build project delivery methods, provide early input into the design | 2 | 10 | 11 | 5 | 2 | 30 | **56.67** | 4 |
| 5 | Simplification of member connections and attached items such as curtain walls can save costs | 3 | 9 | 10 | 6 | 2 | 30 | **56.67** | 5 |
| 6 | The quality of the contract documents | 4 | 17 | 6 | 2 | 1 | 30 | **46.00** | 6 |
| 7 | The use of angles instead of bent plates for the work | 7 | 14 | 5 | 4 | 0 | 30 | **44.00** | 7 |
| 8 | When steel is to be completely enclosed, painting may not be necessary | 11 | 15 | 4 | 0 | 0 | 30 | **35.33** | 8 |

According to the Table 11, there are five factors which are significant as per to RII analysis (>50%). Avoidance extensive field welding is the highest important factor in order to reduce steel construction cost. Steel contractors can concern on importance of above factors at pre-contract stage. Application of above factors may depend on client requirements.

## 5.0 Conclusion and Recommendation

Construction industry is looking for better alternative solution for ever increasing building material prices which directly effects on construction operational and maintenance costs. In-situ concrete has being prominent construction material for building construction in the Sri Lankan context up to recent years. Researcher concerns on steel as an alternative material for building construction. Therefore the researcher's consideration was to determine the cost benefits of steel building construction for Sri Lankan construction industry. However, there are less numbers of steel buildings constructed in Sri Lankan construction industry while steel building constructions was well known worldwide due to its mentioned benefits.

Cost of component of construction was recognized through four factors of production land, labour, material and entrepreneurship. After that cost factors was identified under each factor of production of building construction.
Based on the survey results the identified cost beneficial factors from steel construction were identified as Cost of demolition and removing debris, Labour cost involve in the substructure, frame, slab construction process, and service installation, Material cost of the foundation and slabs construction process, Operational cost for equipments and machineries in the construction, Cost of site utilities in the construction period, Maintenance cost and rentals of site offices and other temporary buildings, Cost for provision of changes and variation in the construction process, Cost for providing insurance for the construction works and Cost allocation for price escalation. However, Cost for find available technologies in the regions, Cost of maintenance the building, Material cost for frame construction process, Land cost for the material storage and lay down in the site lay out, Cost allocation for risk in the construction, Cost for technological aspects of its processes and engineering modelling tools, Cost for consideration of safety measures in the site construction process, Land cost for access and handling heavy machineries like Crane, Trucks in the construction site, Cost for finding the industry standard details in design and Cost for expression functionality and aesthetic of design were identified as less costly with in-situ construction.

In order to reduce such related high costs in steel construction the following steps are suggested by the survey; Avoid connections which require extensive field welding when possible, The use of repetitive members of the same length and size will allow for easier shop drawing development, Close co-ordination by the erector, fabricator, and contractor in project planning for construction, Design-build project delivery methods, provide early input into the design, Simplification of member connections and attached items such as curtain walls can save costs, The quality of the contract documents, The use of angles instead of bent plates for the work and When steel is to be completely enclosed, painting may not be necessary.

However these factors are more applicable within Colombo metropolitan area as the research was carried out base on this area. Furthermore research was done for building construction projects. Besides, cost benefits factors of steel building construction were identified comparing cost factors with in-situ concrete building. Here a hypothetical steel building was considered and which was constructed from steel as the main construction material and some elements of the building are constructed out of different material such as brick or block masonry for walls, precast concrete units or steel deck for slabs and in-situ concrete for foundations.

## 6.0 References

Abeysuriya, N. (2007). *Design fabrication and erection of steel building in Sri Lanka*. Retrieved form http://ebookbrowse.com/design-fabrication-and-erection-of-steel-buildings-in-sri-lanka-by-n-abeysuriya-2007.pdf

Briscoe, G., (1988). *The economics of the construction industry*. London: B.T.Batsford Ltd.

Burke, A. (2011). The entrepreneurship enabling role of freelancers. *E-journal of International Review of Entrepreneurship,* 9(3), 1-26. Retrieved from http://www.senatehall.com/uploads/fck/Burke9_3.pdf

Colander, D.C., (2008). *Macroeconomics* (7th ed.). New York, America: McGraw- Hill/Irwin.

Cooke, J.A. (1996). *Economic and construction*. London: MacMillan Press Ltd. Emimitt, S., & Gorse,C. (2006). *Barry's advanced construction of building*. United Kindom.

Ellobody, E., & Young, B. (2010). Numerical simulation of concrete encased steel composite columns. *Constructional Steel Research,* 67 (2011), 211–222. doi:10.1016/j.jcsr.2010.08.003

Gransberg, D.D., Popescu, C.M., & Rayan, R.C. (2006). *Construction equipment management for engineers, estimators, and owners*. United States of America: CRC Press Taylor & Francis Group.

Harvey, J. & Jowsey, E. (2004). *Urban land economics* (6th ed.). New York: Palgrve MacMillan.

Hedley, D. (2013, March). *Entrepreneurial excellence.* Retrieved from http://www.hardhatpresentations.com/EntrepreneurialExcellence.html

ITP Publishing Group. (2013). *Tallest steel building (2010).* Retrieved from http://www.constructionweekonline.com/article-9180-top-10-worlds-tallest-steel-buildings/1/print.html

Mehta, M., Scarborough, W., & Armpriest, D., (2010*). Building construction principle, materials, and systems* (2nd ed.). United State of America: Pearson Education, Inc.

Mincks, W. R., & Johnston, H. (2004). *Construction Jobsite Management.* DelmarLearning, Clifton Park, NY.

Mrozowski, T., Syal. & Kakakehe, S.A. (1999). Construction management of steel construction. American Institute of Steel Construction: Inc. Chicago, IL.

Mrema, G. C., Gume, L.O., Chepete, H. J., & Agullo, J. O., (2011*).Rural structures in the tropics.Rome*: Vaile delleTerme di Caracalla.

Nordhasus, S., (2005). *Economics*. New Delhi India: Tata McGraw-Hill Publishing Company Limited.

Noton, A., (2010). *Discover the cost effectiveness of steel building for business*. Retrieved from http://www.freearticlezines.com/

Nunnally, S.W. (2007). *Construction method and management* (7th ed.). United State of America: Pearson Prentice Hall.

Panchal, D. R., (2010, August) *Steel-concrete composite building under seismic forces*, Retrieved from http://www.nbmcw.com/articles/miscellaneous/others/18623-steel-concrete-composite-building-under-seismic-forces.html

Popescu, M.C., Phaobunjong, K., & Ovararin, N. (2003). *Estimating building cost*. New York: Marcel Dekker, Inc.

Smith, J. & Jaggar, D. (2007). *Building cost planning for the design team* (2nd ed.). United Kindom: Elsevier Ltd.

Steel Framing Alliance. (2012, December) *Steel is the new green*.Retrieved fromhttp://www.climatevision.gov/sectors/steel/pdfs/Steel-Alliance-Steel-Is-Green-Fact-Seet.pdf

Stone, P.A. (1983).Building *economics design, production and organization* (3rd ed.). Great Britain: Pergamon international library.

Tuknov, M. (2012, February). *Metal buildings-sustainability and flexibility in a cost-effective package*. Retrieved from http://www.hammersconstruction.com/blog/