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CONSTRUCTION SAFETY MANAGEMENT REPORT FOR HIGH-RISE BUILDINGS

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Abstract. Due to the current rapid economic development, all walks of life have also achieved considerable development. Among them, the construction industry is particularly prominent. In the process of modern city construction, high-rise and super high-rise buildings are more and more common. As we can see, there are a lot of accidents happening at the construction site. In order to find the CSFs for safety management, the author uses SPSS software to collect the data from survey and then performs an analysis. This way, the key factors have been found to affect the safety management. In the meantime, the case study is used to verify the key factors and get the correlation between different CSFs. In order to reduce the possibilities of safety problems at construction sites and propose some suggestions to existing problems, the author combines the current situation and CSFs. The aim of the article is to help companies manage construction sites more efficiently, thus promoting the healthy development of the construction industry in Poland.

Keywords: *Construction safety management, CSFs, lean construction, sustainable development.*

INTRODUCTION

After the development of production and consumption in cities around the world has reached a certain level, all cities are actively committed to increasing the number of layers of urban buildings. Practice has proved that high-rise buildings can bring obvious social and economic benefits. Firstly, they can make the population concentrated, and the vertical and horizontal traffic inside the building can be used to shorten the connection distance among departments. They can improve efficiency. Secondly, they can make large-area building land significantly reduced. It is possible to select a site in the centre of the city. Furthermore, they can reduce municipal construction investment and shorten the construction period. The development of modern cities is characterised by high population density. A shortage of land plots for the construction of the sites for different functional purposes raises the cost of vacant sites in cities. It causes an increase in the number of stories in buildings and density of the city development (Kravchunovska et al., 2020). Safety performance is a serious challenge in high-rise building construction with high-altitude operation and excavation of deep foundation pits resulting in much higher accident rates and more severe injuries than that found in low-rise buildings. Injuries and fatalities resulted from falls and the impact of falling objects are constant threats (Li et al., 2018). The present article aims at summarising the

points that can cause the accidents and finding solutions to handle them. Meanwhile, it is necessary to consider the whole process of the construction. This is achieved by increasing the efficiency of utilization of resources while meeting the requirements for efficiency, energy saving, safety, quality, and ecological friendliness of high-rise construction. The study also uses Chan Media Centre building model and Silver Tower of Poznan to perform case study in order to verify the CSFs. Finally, the study combines the current situation in Poland and CSFs in order to propose some useful suggestions of safety management for the future construction process.

1. LITERATURE REVIEW

Generally, success in most construction processes depends on three to six factors. Rockart (1979) states that CSFs represent, for any business, the limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organisation. CSFs are the area of activity that should receive constant and careful attention from management. The construction of high-rise buildings is a popular policy strategy for accommodating population growth in cities (Verhaeghe et al., 2016). Therefore, we need to pay more attention to the construction process, guaranteeing the construction quality. Construction of the high-rise building is a potential strategy for reducing the urban horizontal development growth and impervious land area (Tong et al., 2018).

The government will realise the importance of high-rise buildings in the city. Especially in some big cities, high-rise construction can remit an effect of the area. We need to enhance precautionary awareness and propose an adequate plan to solve the problem.

In order to make the process of construction safe, governments develop different rules to prevent the safety problems happening during the construction process.

2. RESEARCH METHODOLOGY

The study applies a three-pronged research design. Firstly, expert surveys were done by SPSS to get the CSFs of safety management for high-rise building construction which was based on the factors summarised in Table 1. Secondly, a questionnaire was carried out to find the variables which could affect the CSFs. Thirdly, case study was used. The Chan Media Centre model and Silver Tower model were applied to uncover the correlation between different CSFs.

2.1. Expert Survey

The eight experts of construction were interviewed. All of them had good experience at the construction site. The group of experts comprised three project managers and five construction site safety managers. They came from different construction companies, e.g., Chan Media Centre. In order to guarantee the accuracy of the survey, every conversation was conducted independently. The

meeting was held in Changzhou, China, in 2019. The meeting was around the CSFs for safety management. Firstly, the CSFs for safety management were collected from these experts. Secondly, an individual meeting with each expert was organised. Thirdly, the experts had to rate CSFs. The grading scale was from 0 to 5.

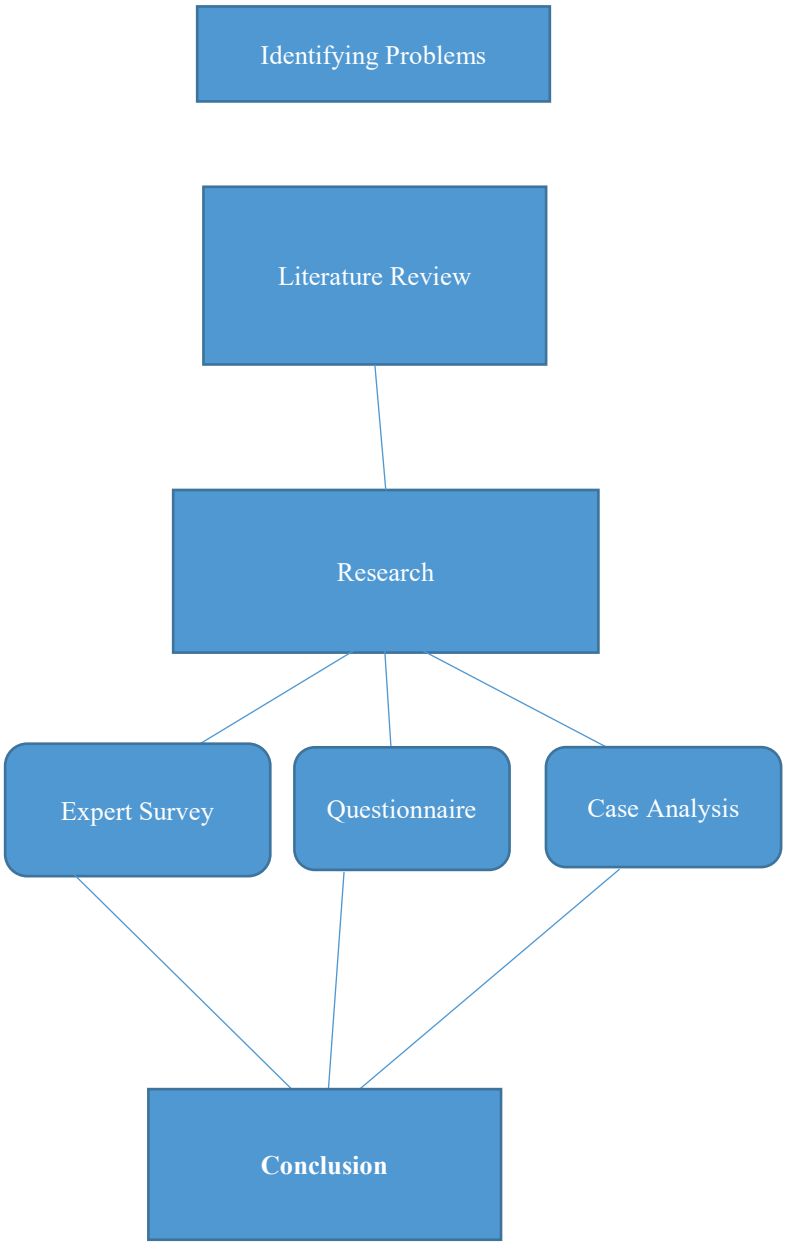

Fig. 1. Project activity flow diagram.

The Statistical Package Social Science (SPSS) software was used to collect the data from the expert survey and then to obtain the result.

Table 1. Factors Affecting Safety Management in High-Rise Construction in SPSS of IBM Done by Pengcheng Ni (Changzhou, China)

Factors affecting safety management in high-rise construction	**Statistics**			
	N	mean	error	Dev
Organisation of safety policy	50	4.0	0.177	0.814
Safety training and awareness	50	4.6	0.134	0.765
Safety meeting	50	3.67	0.211	0.766
Availability of safety equipment	50	4.34	0.243	0.541
Safety inspections	50	4.31	0.243	0.886
Safety incentives and penalties	50	2.1	0.521	0.903
Worker's attitude towards safety	50	4.4	0.755	0.991
Labour turnover rates	50	2.5	0.451	0.525
Compliance with safety legislation	50	3.9	0.411	0.673
Safety measuring devices	50	3.87	0.901	0.966

From the Table 1, we can see that safety training and awareness are vital for safety management in the process of construction. Other critical factors are worker's attitude, safety equipment and so on.

2.2. Questionnaire

The next step of the research was questionnaire. The questions were asked to the experts. These experts had well-educated background. They had adequate knowledge to answer these questions. The questionnaire consisted of five questions sent to the experts' e-mails. They completed it individually. Efficient rate of this questionnaire was around 95 %. The questionnaire also contained basic information of the experts: 1. background of construction; 2. experts' personal ability; 3. experts' basic information. The basic information was aimed at revealing the success factors. In the meantime, the data were the important variables for the research. It would affect the final CSFs.

2.3. Success Factors

From the questionnaire, some important variables were obtained. These variables are shown on Figs. 2–4.

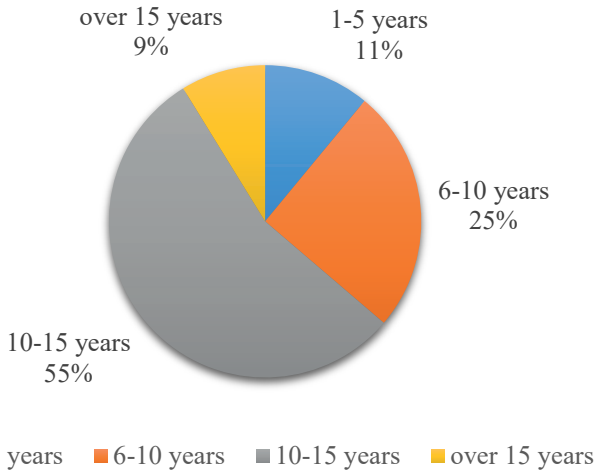

Fig. 2. The professional experience in safety management.

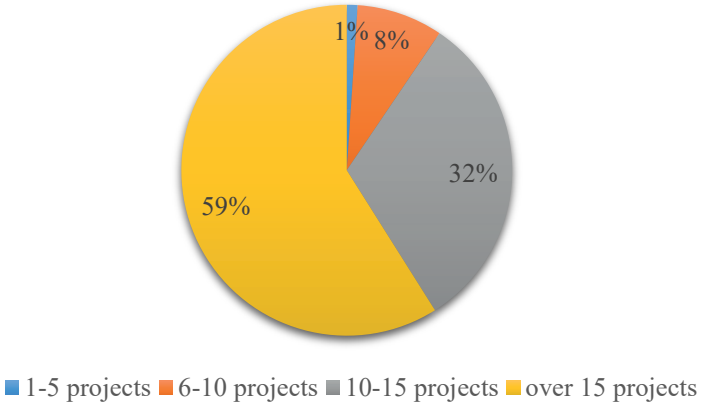

Fig. 3. The number of completed projects.

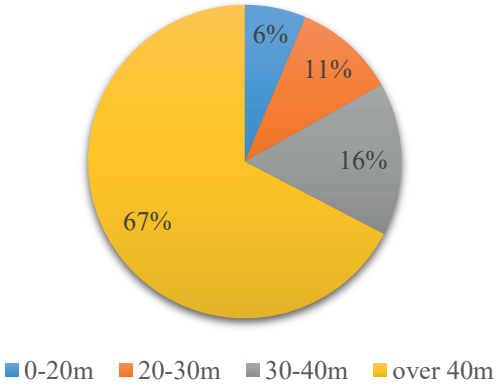

Fig. 4. Height of buildings.

Kaiser-Meyer-Olkin Measure and Bartlett's test are used to show the value of these data.

The Kaiser-Meyer-Olkin Measure of Sampling Adequacy is statistic that indicates the proportion of variance in variables that might be caused by underlying factors. High values *(close to 1.0)* generally indicate that a factor analysis may be useful with the data. If the value is less than 0.50, the result of the factor analysis probably will not be very useful. For Bartlett's test of sphericity, the hypothesis shows that the correlation matrix is an identity matrix, which will indicate that variables are unrelated and therefore unsuitable for structure detection. Small values *(less than 0.05)* of the significance level indicate that a factor analysis may be useful with the data. In the present research, the Kaiser-Meyer-Olkin value is 0.7. It is far from the 0.5. It means that all the data are valuable. Bartlett's score for questionnaire is 3100, and the associated importance level is 0.000, indicating that the correlation matrix is not an identity matrix.

Cronbach's alpha formula

$$\text{For } \alpha: \alpha = NC/[\bar{\upsilon} + (N-1)C], \quad (1)$$

where

N is equal to the number of items;

C is the average inter-item covariance among the items;

$\bar{\upsilon}$ equals the average variance.

The alpha coefficient of all the data is below 0.839, suggesting that the items have relatively high internal consistency (Cheng et al., 2004).

Table 2. CSFs Points of Construction Projects

Cluster	Success factor	Value	Factor loading	Cronbach's α	Factor label
CSF1	Safety meeting	0.746	0.754	0.775	Management ways
	Safety inspections	0.812	0.653		
	Safety incentives and penalties	0.699	0.545		
	Organisation safety policy	0.803	0.723		
CSF2	Safety measure devices	0.691	0.727	0.743	Technology
	Availability of safety equipment	0.801	0.712		
CSF3	Safety training and awareness	0.792	0.595	0.821	Workers
	Workers' attitude towards safety	0.754	0.658		
	Compliance of safety legislation	0.732	0.771		
CSF4	Labour turnover rate	0.722	0.691	0.65	Plan

From Table 2 we can see that the third group has the highest value. Cronbach's α is the greatest. It means that the factor of workers has a great significance for the safety management.

2.4. Case Analysis

Now, we can come back to the Chan Media Centre. We know that the worker factor will affect the safety management deeply. This building started to be built in 2013. An accident happened in the middle of 2014. A worker fell down into the foundation pit. The project manager organised a meeting to solve the problem, in order to prevent safety accidents happening again. Before the construction started, the construction company had regulated a list of planning to avoid safety problems happening. The contractor took a lot of measures:

1. Setting up fences around the construction work area and other safety equipment.
2. Conducting construction safety training.
3. Carrying out periodic inspection.

After finishing the case analysis meeting, we get the result. Before the worker came there, there was a heavy rain. The rain crushed the soil. It made the soil become very soft and smooth. And then, the worker was not aware of the danger of site after raining.

We can know it clearly. The main reason that caused this accident was that the worker lacked the awareness of protecting himself. Other factors also affected this accident, such as weather.

The author examined the Silver Tower of Poznan. The author actually visited the construction site and found that the safety facilities at the construction site were very complete. There is a dedicated person to patrol the site, and there is no problem of messy stacking of construction equipment and materials. Different workers work in their posts and strictly follow the requirements of the construction operation regulations. The construction site is fenced to prevent someone falling down into the foundation pit. Till now, there has not been an accident at the site. This contractor *(Porr)* also keeps a good record of no casualties in Poland. From this case, we can find the importance of CSF3 in safety management of high-rise buildings. This case proves that CSF3 is the key part.

Compared with the rate of every important factors that will affect the safety in Chan Media Centre project, the average rate for workers who can follow the rules of operations in the silver tower is 99 %. In the Chan Media Centre project, the rate is 60 %. Other factors are similar. We can see clearly that workers' awareness and training will affect the safety of project. They play a very important role in the project.

The same questionnaire was sent to the project manager and the safety manager. They had worked before at another construction company. They had some other thoughts about safety management. They had experience in different construction projects, too. They summarised the accident rate and some important factors, which could cause the safety accidents.

Summarising the data collected, it was found that the CSF3 was developing quickly as the CSF1's development. The relationship between CSF1 and CSF3 was

analysed. It was found that CSF1 would affect the development of CSF3. We focus on different projects. For example, we hire more safety managers to stay at the site. We can see that the rate of construction workers complying with operating regulations is increasing. The duration is one month. We assume that one month contains 30 times of meeting. The rate for CSF1 means the number of meetings as a percentage of the total number of meetings.

Table 4. CSF1 & 3 Rates in Different Projects

	Project 1	**Project 2**	**Project 3**	**Project 4**	**Project 5**
CSF1 rate	50 %	60 %	70 %	80 %	90 %
CSF3 rate	75 %	79 %	84 %	91 %	97 %

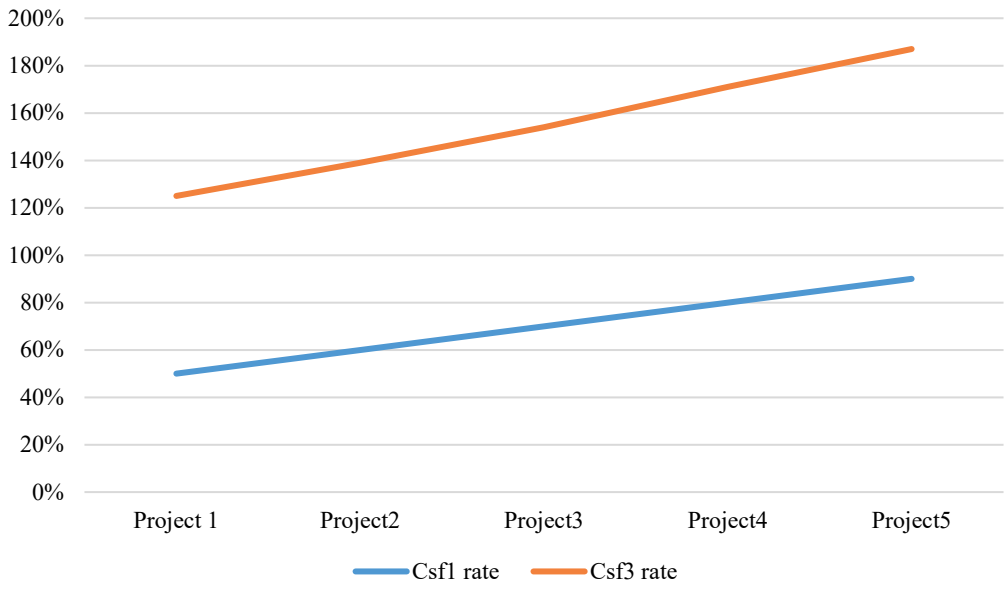

Fig. 5. Trends in the correlation between CSF1 and CSF3.

We can see that as the development of CSF1, the CSF3 also develops very quickly. From this point, we can think that CSF1 and CSF3 are positively correlated, and CSF1 promotes CSF3.

2.5. The Interaction among CSFs

The intersection theory states that workplace accidents are the result of a combination of unsecured environment and unsafe behaviour, meaning the traces of the safety environment and worker behaviour may intersect to cause accidents (Khan et al., 2015), so CSF1 will affect CSF3. In case of the Chan Media Centre,

we can see that the lack of inspection also caused this accident. If there were dedicated personnel on duty at the construction site, the situation would not be bad.

In the domino theory by Bird et al. (1974), the direct causes of accidents are unsafe conditions and unsafe human behaviour, whereas the root cause of accidents is management defects.

2.6. Comparison between Regular Timber Houses and High-Rise Buildings

As we can see, there are a lot of regular timber houses in Poland. In order to know the safety accident incidence at the construction site of timber houses, the questionnaire was sent to the same experts that had been previously interviewed. They also had the strong experience in construction of timber houses. The number of samples in timber houses is 100 units. The number of samples in high-rise buildings is 100 units. Under the exact calculations, the average safety accident incidence of timber houses is 95 %, and the rate for high-rise buildings is 80 %. The significant influencing factor for high-rise buildings is foundation construction. It accounts for 60 % of the overall accident incidence in the sample. As for the timber house, it is only 5 %. From this point, we can know that we need pay more attention to the foundation construction in high-rise buildings. From the interview with experts, it was found out that regular timber houses had very shallow foundation due to the height limit. On the contrary, the high-rise buildings have deep foundation in order to satisfy the bearing capacity. Deep foundation may cause more safety problems. In light of this point, we should take strict measures to prevent accidents of foundation construction when we compare it with timber houses. Based on CSF3 and CSF1, we should strengthen the management of workers at the foundation construction stage. High-rise buildings in Poland are still developing. There will be more high-rise buildings in Poland in order to mitigate the pressure of housing supply. Due to the special geographical location of Poland and political economic influence, it will attract more and more immigrants. It is necessary to develop stringent standards and implement them strictly in order to reduce safety accidents at construction sites of high-rise buildings. When recruiting construction workers, it is necessary to strengthen the inspection of the quality of the workers themselves. These measures can effectively improve the safety management level of construction sites, reduce the incidence of safety accidents and promote the healthy development of the construction industry in Poland.

CONCLUSION

High-rise building construction is a complex process influenced by numerous and variable factors. Excellent safety management performance plays an essential role in construction project success. By examining the data and performing the case analysis, it has been determined that workers play a very important role in the construction safety management system. As the current construction workers' general awareness of accident prevention is weak, it is necessary to strengthen workers' education of safety. Relevant departments need to actively coordinate the re-education of workers, improve workers' safety awareness, and turn the building itself and the construction process into a harmoniously developed whole.

In addition, case studies for high-rise building construction projects could be performed within the scope of further research.

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