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Improving Hazard Identification, Risk Assessment and Risk Control (HIRARC) Implementation in Industrialized Building System (IBS) Construction Projects

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Abstract: The hazards for conventional construction methods are different from the hazards for Industrialised Building system (IBS) construction methods. The differences are due to the distinct construction method applied, however the consideration for safety for both methods are crucial to ensure the project success. In order to decrease the likelihood of accidents occurring on the IBS construction projects, the hazards, risk and their preventive measures must be taken into account. Therefore, the objectives of this paper is to identify the current implementation of Hazard Identification, Risk Assessment and Risk Control (HIRARC) during the IBS construction and to recommend the improvement of safety level on IBS construction using HIRARC. A quantitative approach by means of questionnaires is carried out, the questionnaires are distributed to the IBS constractors in Klang Valley area. It is found that most activities in the HIRARC are moderately applied in IBS construction and the improvement based on HIRARC have been recommended in order to improve the safety. The findings of this paper is perceived to assist the construction companies in understanding and implementing the HIRARC during the IBS construction project.

Keywords: Hazard, Safety, Prefabrication, IBS, Construction Project

1. Introduction

Industrialized Building System (IBS) was introduced as new innovative construction method as this method has a potential solution to increase the performance in terms of time, cost and quality as well

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as the safety aspect of a construction project (Nasir *et al*., 2012). IBS is a method which includes any construction system that applied large quantities of precast and pre-fabricated components from factories and being transported to construction site for installation (Yashrri & Hanizam, 2014). Malaysia's government is enthusiastic about IBS implementation thus actively supporting it and encouraging the transition of construction method from a traditional to an industrialized perspective (Abas *et al*., 2018)

Even though the IBS offers many benefits however its implementation still facing various issues, one of it is safety issues during the construction process (Jabar et. al., 2013). Several accidents have been found which majority of it involved with cranes and fallen objects during the IBS construction process (Nasir *et al*., 2012). IBS process started with manufacturing, followed by delivery, installation and finishing. These processes are not spared from danger as it involves many risky work (Yashrri & Hanizam, 2014). During manufacturing phase, all components usually made at factory. Many plants and equipment with high voltage power are used to produce the component. Meanwhile, at the delivering phase, the safety aspect is focused on the road which is involved with transportation of the component to the site. The most challenging stage is installation and finishing stages where the activities like placing, lifting, and connecting of the IBS component is done on this stage which required the changes on safety practices as compared to the conventional construction (Nasir *et al*., 2012).

Additionally, the importance of safety in the site management cannot be neglected, as it can help to avoid hazards that contribute to the negative outcomes on the project. The strategy to avoid hazards is to reduce the number of accidents that occur by increasing safety procedures and taking into account safety concerns on construction sites. Safety management requires duties such as planning, identifying problem areas, organizing, managing, and directing safety actions on the job site, all with the goal of preventing accidents and illness (Ismail *et al*., 2013). According to The Malaysian law under Occupational, Safety, Health and Act (OSHA), HIRARC is required in order to make the environment on construction site are always in good safety condition (Shaleh & Leman, 2016). Ahmad *et al*., (2016) defined a hazard identification and risk assessment are processes that are used to detect and analyses existing and potential hazards on a jobsite, as well as to control or eliminate the hazards identified.

2. Literature Review

2.1 Hazard Identification, Risk Assessment and Risk Control (HIRARC)

Shaleh & Leman (2016) addressed that hazard identification, risk assessment, and risk control (HIRARC) is the process of controlling risks that have been recognized as potentially causing or contributing to accidents in order to manage related work risks. HIRARC application will allow organizations to continuously assess, monitor, and manage the occupational safety and health risk, thus accidents at work will decrease as the risk is reduced. HIRARC also covers risks involved in both new and existing processes, allowing for full risk identification and management. According to Ahmad *et al*., (2016) those who have already conducted risk assessments at work have noted improvements in their working methods. They also detect when poor acts and working conditions arise and take the appropriate corrective action. In order to ensure that the results are accurate, and the analysis is thorough, the legislation ensures that this procedure be systematic and documented. The process of risk assessment should be ongoing and not seen as a one-time activity. Figure 1 shows the process of HIRARC.

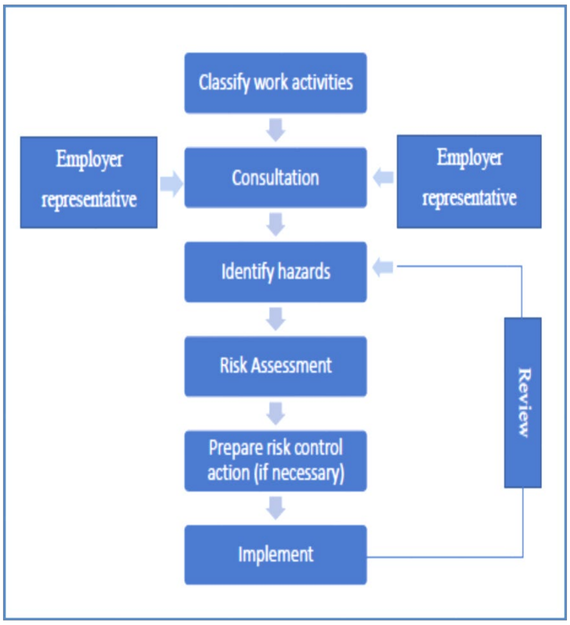

Figure 1: HIRARC Process (DOSH, 2008)

According to DOSH, (2008), the purpose of hazard identification is to highlight the critical operations tasks, tasks posing significant risks to the health and safety of employees as well as highlighting those hazards pertaining to certain equipment due to energy sources, working conditions or activities performed. Hazards can be divided into three main groups, health hazards, safety hazards, and environmental hazards. Hazard can be identified through seven sources such as workplace inspection, accident investigation,knowledge sharing, injury/illness report, safety audit, complaint and obsevation, health and environment monitoring.

Meanwhile, the risk assessment is the risk presented in communicating the result analysis in order to make decision on risk control. For risk analysis that uses likelihood and severity in qualitative method, presenting result in a risk matrix is a very effective way of communicating the distribution of the risk throughout a plant and area in a workplace. According to Ahmad *et al*., (2016) the measurement is made by determining how serious and when the risk is likely to occur. In other words, risk assessment is a thorough examination of situations, procedures, and other hazardous workplace behaviors or hazards. Decisions on risk control must be based on the outcomes of risk assessment as provided in a risk matrix. According to Shaleh & Leman, (2016), estimating the size of a risk and determining if it is workable are steps in the risk assessment process. It could be evaluated to determine the "likelihood" and "consequence" of a specific hazardous occurrence occurring or hurting a worker. A suitable course of action might be taken to minimize the risk level that can be approved as a safe workplace if it is thought to be high risk and unsafe to deal with.

On the other hand, as mention by Shaleh & Leman (2016), risk control is the elimination or inactivation of a hazard in a manner that the hazard does not pose risk to workers who have to enter into an area, or work on equipment in the course of scheduled work. Hazards should be controlled at their source (where the problem is created). The closer a control to the source of the hazard is the better. This method is often referred to as applying engineering controls. If this does not work, hazards can often be controlled along the path to the worker, between the source and the worker. This method can be referred to as applying administrative controls. Risk control it is required to carry out comparable tests and trials or to compare to standards in order to reduce or prevent the hazards. The "hierarchy of OSH control" is the most often used method for introducing and putting into practice risk control measures. There are several options, including personal protective equipment, engineering controls, substitution, isolation, and administrative controls (PPE).

2.2 Industrialised Building System (IBS) and common accident in IBS construction project.

The industrialized building system is defined as a construction technique in which components are manufactured in a controlled environment on-site or off-site, transported, positioned, and assembled into a structure with minimal additional site work (Othman *et al.,* 2017) as shown in Figure 2. The implementation of the Industrialized Building System (IBS) in Malaysia has started as early as in the 1960s. Through standardization, specialization, and mass manufacturing, the technique had shown to provide high-quality buildings, on-time completion, cost savings, cleaner construction and grater safety thus, due to these benefits the Malaysian government has actively pushed the use of IBS in the construction industry (Jabar *et al*., 2013). IBS can be classified into six basic categories which are precast concrete systems, formwork systems, steel framing systems, timber framing systems, blockwork systems, and innovative. Any system that is not entirely built on concrete, block, steel, or wood falls under innovative system, which appeared in 2010 (Al-Aidrous *et al.,* 2021).

Shaari *et al*., (2016) stated that IBS components which has been prefabricated at factory must be transported with care from the to the installation site. The installation process which normally involved with heavy machinery and equipment should be done in greatest safety consideration to avoid any injury. Unsafe behavior on during the installation process will resulted to accidents. Lifting, welding, grouting, bracing, and placement are the four processes involved in the installation of an IBS system. All these processes are carried out by the IBS installer and must be successfully erected while at the same time given consideration to the safety aspects.

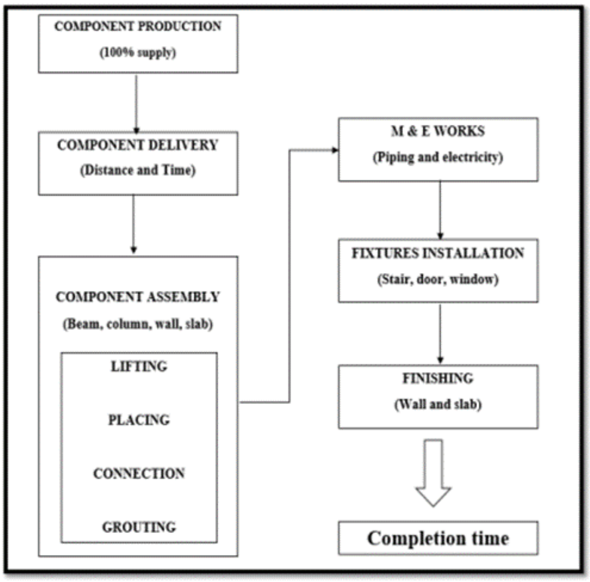

Figure 2: IBS Construction Process (Othman, 2017)

According to Chopade *et al*., (2021), common accidents in IBS Construction projects normally happened during the installation/assembly process, such as falling from a height, crashing of precast elements, struck by a vehicle, failure of hooks and wire ropes , crashing of reinforcement cage and hoist cable breakage. IBS installation requires a lot of working at high. Working above a specific height presents several risks, including the risk of people falling and the risk of heavy things falling, both of which can result in significant injuries if dangerous techniques, insufficient edge protection, or improper PPE use. Meanwhile prefabricated structures like girders and shear walls that fall during lifting could seriously damage the structure and endanger the nearby workers. Slips that occurred while raising the elements may be the cause of this.

Since, IBS installation is a machanised process which 100% utilised the plant and machinery thus fall, being hit by falling objects and overexertion in lifting objects are several examples of accidents that caused by plant and machinery. Certain machineries, such as crane, lift/elevator, and lorry are common involved in accident. Accident involving cranes, which are usually used for transporting and lifting, are extremely critical (Ayob *et al*., 2018). Further, according to Zaki *et al*., (2016) according to survey, 18.6% accidents during IBS construction are caused by the equipment and machinery. Inspection on equipment and machineries need to be focused to check the condition and to make sure it is approved by the authority (DOSH).

Accidents during installation may also resulted from carelessness and misunderstandings between the hoist and crane operator and the instructor. It harms the surrounding workers as well as the hoisted items. There is also accident that caused by hoist cable breakage. This kind of accident is due to the main hoist rope breaking when lifting items caused by internal fracture and many other reasons, it may result in the loss of life and resources, as well as unnecessarily delay the project (Chopade *et al*., 2021).

2.3 HIRARC in IBS construction project.

IBS project started with component production. According to Abas & Blismas, (2021), the activities involved in component production of IBS e.g precast wall panel include bar cutting; bar bending; cage inspection; mould setting; cleaning of mould and oiling; placing reinforcement in cages and setting embedded items into mold; tying bar; positioning the mixer truck; concreting, vibrating and surface finishing; dismantling molds; finishing using skim coat; and transferring the components to storage. Associate hazards related to the activities during this process should be identified for risk assessment purpose. The hazard is mainly related to the careenage of large mold's and components, ergonomic-related hazard, exposure to UV, the assembly of steel bar and electrical shock from the electrical equipment used, the use of chemicals in the activities of cleaning and oiling the mold's, and also the finishing of components using a skim coat. In vibrating and compacting concrete, the main hazard highlighted were dermatitis, careenage (from the overhead concrete bucket attached to the overhead crane) and manual handling. Positioning of the mixer truck included the hazard of mobile plant (vehicle injury). Mechanical handling and careenage associated with the hazard in moving and storing the panels.

The second process in IBS construction is component delivery. The hazard was associated with the delivery of materials to the construction site, which are road traffic, site access, site conditions and the stability of materials. In addition, mobile plant risks during loading and off-loading were also significant hazard.

Next is component installation, the hazard identification during the installation of IBS is crucial due to the involvement of heavy component and plant and machine. The process involves are lifting, placing, welding, and grouting. Among associated hazard during lifting process are hazards related to the loads in crushing aspect due to impact of moving objects or loads falling from vehicles because they are not sling properly or the wrong type of slings were used. Hazards from moving vehicles or collapsing structures, for example; cranes falling over because of improper fixation or strong wind, unsafe loads, loads exceeding the safe weight limits, falling from lifting platforms or being crushed when the platform moves. Musculoskeletal hazards related to force exertions, poor working postures and/or repetitive work, hazards related to poor environment that may interfere with communication between workers or concentration needed for the task (noise) or cause sweaty, slippery objects (heat, poor ventilation) and contact with overhead electrical cables (Othman, 2017).

During the placing process, the spaces provided must be appropriate to place all the items either machinery or components. Installer also needs to recheck and track the adequacy and suitability of components once it arrives at site (Othman, 2017). Meanwhile, during the welding process, the hazard associated are mainly to body injury such as the eye injuries. On the other hand on the grouting process, for safety aspect, the workers should wear fully personal protective equipment (PPE) such as liquid resistance glove to prevent hazard from grout mixture whcih contains high quantity of chemical. This PPE is needed to protect workers against the health effects of exposure chemical in grout mixture.

3. Research Methodology

A quantitative data collection has been selected for this study. Questionnaires are used to collect data to achieve the objectives on to identify the current implementation of Hazard Identification, Risk Assessment and Risk Control (HIRARC) during the IBS construction and to recommend the improvement of safety level on IBS construction using the Hazard Identification, Risk Assessment and Risk Control (HIRARC). Hundred (100) set of questionnaire have been distributed via email to the IBS contractors that have been identified through CIDB website. The contractors were contacted by phone call to inform them about this survey and later an email consist of the questionnaire were sent to them. Only thirty-three (33) respondents responded to the questionnaire which makes 33% response rate. The data collected were analyzed using manually using Microsoft Excel with the formulation of Average Index.

4 . Result and Discussion

The questionnaires were sent to the IBS contractors registered with CIDB. Figure 3 shows the composition for position of the respondents. The majority of the respondents are site supervisor, comprising of 49%. Others are project manager (18%) and safety and health officer (33%).

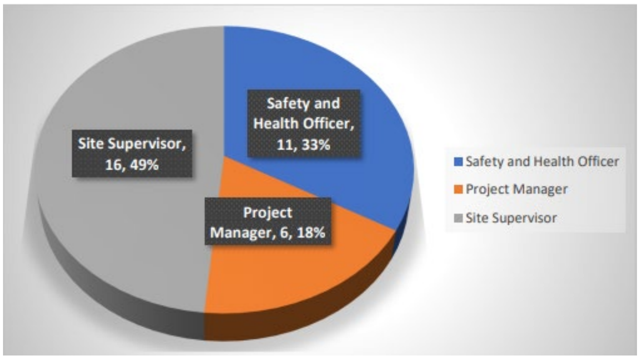

Figure 3: Composition of the respondents

4 .1. The implementation of hazard identification, risk assessment and risk control (HIRARC) at IBS construction projects.

Table 1, Table 2, and Table 3 show the ranking of the implementation of hazard identification, risk assessment and risk control at IBS construction projects. Only the top three in the ranks will be discussed in this paper.

Table 1: Ranking on hazard identification implementation

No	Description	Mean Value	Level of Implementation	Rank
1	Accident investigation	4	Fully implemented	1
2	Workplace inspection	3.82	Fully implemented	2
3	Health and environment monitor	3.61	Fully implemented	3
4	Safety audit	3.36	Implemented	4
5	Employee complaint and observation	2.67	Implemented	5
6	Incident injury / illness report	2.55	Implemented	6
7	Knowledge sharing from consultant	2.33	Partially implemented	7

Based on Table 1 the highest mean value for the implementation in hazard identification is 4.00 which is accident investigation. Completing an accident investigation will be useful in creating safety hazards or safety precautions that must be addressed to lessen the risk of further injuries. Accident investigation can help the management team learn from previous accident cases. Next, the second highest of the mean value is 3.82 which is workplace inspection. An inspection allows management team involved to discover hazards or inefficient processes and decide what steps to take before they cause an accident. Workplace inspection can detect any hazard and inefficient process especially during lifting, welding, grouting, bracing, and placing process. All these processes must follow the guidelines and standard of procedures. The third highest mean value is 3.61 is health and environment monitoring. Environmental monitoring can reduce an organization's impact on the environment and limit risks of dangerous impacts on the natural environment such as soil condition, weather condition, and so on to preserve human health.

Table 2: Ranking on risk assessment implementation

No	Description	Mean Value	Level of Implementation	Rank
1	Identify the hazard	3.64	Fully implemented	1
2	Record significant findings	3.36	Implemented	2
3	Review assessment and revise	3.36	Implemented	3
4	Evaluate the risk arising from the hazards and decide if the precautions already in place are adequate	3.33	Implemented	4
5	Identify potential person that might be harmed by hazards	2.33	Partially implemented	5

Table 2 shows that the highest mean value for the implementation on risk assessment is 3.64 which is identify the hazard. Identify the hazard can help the management team to analyze the risk factors and look at all workspaces and activities with the aim on finding all the associated risks especially on dealing with heavy machineries and installation process to make sure the common accident in IBS construction is avoided. Next, record significant findings and review assessment and revise shared, is the second highest mean value which is 3.36. These two activities are important after hazard has been identified. All findings need to be recorded and listed. After all the findings have been listed and recorded, the assessment needs to be reviewed to ensure there is no further precautions are needed and should be reviewed if there is any change on work nature that may increase the risk. The third highest is evaluating the risk arising from the hazards and deciding if the precautions already in place are adequate. This activity is implemented among the respondent's company. Evaluation is important to help the management team reflect and prepare the method to manage the risk. After making an evaluation, the management team will make sure that the precautions taken are helpful in reducing the risk.

Meanwhile, Table 3 shows the highest mean value for the implementation on risk control is 4.00 which is protect the worker with personal protective equipment (PPE). This activity is fully implemented because PPE is a must item for every sector to protect workers' safety and health. Next, the second highest mean value is 3.79 which changes the way people work (e.g., procedure changes, employee training, and installation of signs and warning labels). In IBS construction, it is important for the management to provide training and prepare the proper guidelines and standards operating procedures since this method involves various types of installation process. Then, the third highest mean value is physically removing the hazard. Most companies eliminate the risk and hazard at it sources before it becomes a problem to the works and environment. Physically removing the hazard is important in IBS construction especially during lifting and handling the machinery and clear the designated pathways before allowing any machineries to pass the way can avoid any accidents.

Table 3: Ranking on risk assessment implementation

No	Description	Mean Value	Level of Implementation	Rank
1	Protect the worker with Personal Protective Equipment (PPE)	4	Fully implemented	1
2	Change the way people work (e.g., procedure changes, employee training, and installation of sign and warning labels)	3.79	Fully implemented	2
3	Physically remove the hazard	3.73	Fully implemented	3
4	Keep the hazard from reaching the worker (e.g., use mechanical lifting device, use technology and machineries rather than human power, etc.)	3.30	Implemented	4
5	Replace the hazard (e.g., hazardous products, machines, etc) with a less hazardous one	2.30	Partially implemented	5

4.2. Improvement of Safety Level on IBS Construction Using the Hazard Identification, Risk Assessment and Risk Control (HIRARC).

Table 4: Ranking on hazard identification improvement

No	Description	Mean Value	Level of Agreement	Rank
1	Observe and take an action to all worker's complaint	3.73	Strongly agree	1
2	Inspect that designated pathways before allowing any machineries to pass the way	3.67	Strongly agree	2
3	Conduct safety audit to assure that effective program elements are in place for identifying, eliminating, or controlling hazards	3.67	Strongly agree	2
4	Share safety knowledge on potential hazard to all contractors	3.61	Strongly agree	3
5	Investigate the roots causes of accident (if any accident appears before)	3.52	Strongly agree	4
6	Monitor the health and environment (e.g., disaster preparedness, hazardous material, climate change, etc.)	3.52	Strongly agree	4
7	Record all incident injury and illness report	3.48	Agree	5

Based on Table 4 the highest improvement for risk identification is observed and act to all worker's complaint. Workers are the people that know very well about nature on site. Therefore, complaints that come from workers need to be observed and action needs to be prepared on those complaints. Next, there are two improvements that share same rank with 2.67 mean value; inspecting the designated pathways before allowing any machineries to pass the way and conduct safety audit to assure that effective program elements are in place for identifying, eliminating, or controlling hazards. Sharing safety knowledge on potential hazards to all contractors becomes the third highest improvement suggested. Most respondents agreed that this activity is crucial because the sharing session by the consultant can create awareness to the workers especially on high-risk projects.

Table 5: Ranking on risk assessment improvement

No	Description	Mean Value	Level of Implementation	Rank
1	Identify the hazard	3.64	Fully implemented	1
2	Record significant findings	3.36	Implemented	2
3	Review assessment and revise	3.36	Implemented	2
4	Evaluate the risk arising from the hazards and decide if the precautions already in place are adequate	3.33	Implemented	3
5	Identify potential person that might be harmed by hazards	2.33	Partially implemented	4

On the other hand, Table 5 shows the mean value analysis by ranking for improvement on risk assessment. The highest is review assessment, revise, and check if the control measures are working. This task can ensure that all precautions that have been taken are suitable with the current nature of site project. Next, the second highest is listing out and identifying all potential hazards before lifting, installation and other works. Taking immediate precautions to control the risk is the third highest recommendation with 3.52 mean value.

Table 6: Ranking on risk control improvement

No	Description	Mean Value	Level of Implementation	Rank
1	Protect the worker with Personal Protective Equipment (PPE)	4	Fully implemented	1
2	Change the way people work (e.g., procedure change, employee training, and installation of sign and warning labels)	3.79	Fully implemented	2
3	Physically remove the hazard	3.73	Fully implemented	3
4	Keep the hazard from reaching the worker (e.g., use mechanical lifting device, use technology and machineries rather than human power, etc.)	3.3	Implemented	4

5	Replace the hazard (e.g., hazardous products, machines, etc) with a less hazardous one	2.3	Partially implemented	5

Table 6 shows the mean value analysis by ranking for improvement on risk control. The highest recommendation is to provide suitable and proper Personal Protective Equipment (PPE). The employer must ensure that the provided PPE is sufficient and effective to protect the worker from occupational dangers. Next, the second highest recommendation is following the designated pathways and keeping clear of site traffic and machinery. This activity is crucial and highly recommended because IBS is fully operated by machineries to lifting and assembling. Good, designated pathways and clear site traffic can prevent any accident. The third highest recommendation is providing adequate precast storage and locking away dangerous equipment and substances. Adequate precast storage is important to keep all precast just in one location to avoid the item harming the workers and also to make the site look safe for the machinery to use the way.

5. Conclusion

This study attempts to identify the current implementation of Hazard Identification, Risk Assessment and Risk Control (HIRARC) during the IBS construction and to recommend the improvement of safety level on IBS construction using HIRARC. IBS construction project is different from conventional construction project, it involved with the process of manufacturing, delivery, and installation of component. Thus, identifying and ranking the currently implemented HIRARC is crucial to carry out for further improvement on its implementation. Meanwhile, the recommendation for HIRARC improvements specifically in IBS construction project were also ranked by its importance thus it is hoped that the improvement can be considered during IBS construction project to prevent and decrease the likelihood of accident during IBS construction especially during installation phase.

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