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BENEFITS AND BARRIERS FOR POKA-YOKE IMPLEMENTATION TO MINIMISE VARIATIONS IN CONSTRUCTION PROJECTS

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Abstract: Variations are inevitable in any construction project. People tend to view variations as a natural and inherent part of construction work, due to the complexity of the construction project. Lack of knowledge, inexperience, and wrong expectations frequently caused variations and eventually lead to exceeding the project cost. Hence, minimising variations in construction projects is vital to the sustainable delivery of the project. Poka-Yoke is a Japanese mistake-proofing method that received wider recognition in the service industry. However, there is a lack of research on how Poka-Yoke can be implemented to minimise mistakes in construction projects. Therefore, this research is aimed to investigate the benefits and barriers of Poka-Yoke implementation for Sri Lankan construction projects to minimise variations. To collect qualitative data, semi-structured interviews were conducted with experts, and code-based content analysis through NVivo 12 was used to analyse the data. As Poka-Yoke is novel to the Sri Lankan construction industry, the identified nine barriers will pave the way for professionals to avoid the existing barriers by taking necessary precautions prior to implementation. Thus, the findings further emphasised the need for the government to provide proper knowledge through training sessions. The identified fifteen benefits will be encouraged professionals to use Poka-Yoke to minimise the causes of variations in construction projects. The construction industry professionals, Engineers, Architects, and Quantity Surveyors have to bind their greatest involvement during the designing stages to minimize the variations and thus benefit from the research findings.

Keywords: *Barriers; Benefits; Construction industry; Poka-Yoke; Sri Lanka*

1. Introduction

Bakr (2014) revealed that the most active sector in any country's economy is the construction industry, and it can be used to evaluate the performance of an economy. While the construction industry is identified as the most complex and uncertain sector, due to its unique characteristics (Oladapo, 2015; Ilyas, Li, & Ullah, 2019; Alsuliman & Bowles, 2012), the possibility of making changes is a matter of reality in the construction project. A variation is regularized through issuing a formal document named variation order in the construction industry (Balbaa, El- Nawawy, Ek-Dash, & Badawy, 2019). There are specific causes for variations, and it is a common phenomenon in construction projects. The causes for variations are categorised as client-related variations, consultant-related variations, contractor-related variations and non-party causes called "other causes variations." It directly links causes and originators to variations (Sertyesilisik, Ross, & Keane, 2010). However, clients and consultants are leading creators of variations (Assbeihat & Sweis, 2015; Mohammad, Che Ani, Rakmat, & Yusof, 2010; Bakr, 2014; Muhammad, Keyvanfa, Dankaka, & Magana, 2015) comparing to causes for contractor originated variations. Johnson and Babu (2020), and Muhammad et al. (2015) elicited one of the leading causes for variations as other causes apart from client and consultant causes. In detail, the client's financial problem, lack of effective communication, change in the design by the consultant, technology changes, inadequate working drawing details, and increasing project complexity can be considered as some of the causes for variations (Arain, Assaf, & Pheng, 2004). These causes of variations are largely disturbing the project performance.

The most frequent effect of variation is the increase in project cost (Amri & Marey-Pérez, 2020; Arain & Pheng, 2005; Musarat et al., 2020). Furthermore, Sanni-Anibire, Mohamad Zin, and Olatunji (2022) point out that variations also cause delays in construction projects. Further, the variations could be an initial source for cost and time overruns in construction projects (Johnson & Babu, 2020). Therefore, Mahmoud and Elshaikh (2019), and Senarathna and Sexton (2011) stated that productivity loss, interruption of workflow, and cash flow problems are the effects of variations, leading to claims and disputes between the parties in the construction project. Still, the existing evaluation method for variations also grounds disputes and claims between the parties to the contract (Bower, 2000). However, Arain and Pheng (2005) specified that the variations might be an unwanted concept in the construction

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process. Variation in the construction projects would be a situation that results in alternation to actual tasks, implementation duration, total cost (direct and indirect), and working quality (Ibbs, Nguyen, & Lee, 2007; Mahmoud & Elshaikh, 2019). Perera, Sirimewan, and Senadeera (2021) indicate that the main effects of these variances in Sri Lankan construction projects include time and cost overruns, demolition, rework, and disputes. Due to these variations, Sri Lanka, another growing nation, faces numerous problems with construction management (Halwatura & Ranasinghe, 2013). Further, variations have a negative effect on the time, cost, and quality of the construction projects carried out in Sri Lanka (Gunarathna, Yang, & Fernando, 2018). Moreover, twenty Sri Lankan residential projects that were recently completed were examined, and it was discovered that time overruns were 99% of the anticipated project duration and cost overruns were 15% and 35% of the initial contract value, respectively (Jayawardena, Ramachandra, & Rotimi, 2014).

The adverse effects on construction project performance can be mitigated through managing variations. Hence, understanding the cause of variation and the impact of variations is essential to minimize variations (Eigbe, 2016). The client's benefits can optimize the value for money against the input resource by eliminating unnecessary additional costs related to variations (Muhammad et al., 2015). Considering all the impacts of the variation, the construction project shows a different output compared to its planned stage due to variations. Therefore, there is a necessity to be made in the mechanism to minimize variation in construction projects. Hence these effects might be mitigated if the causes are avoided before variations occur. Perera, Sirimewan, and Senadeera (2021) emphasised that the measures most likely to reduce variations in Sri Lankan construction projects are a preliminary investigation, a detailed employer's brief, a comprehensive design and set of specifications, and clearly stated project objectives. However, an ideal principle should be capable of minimizing variations by identifying errors and mistakes of the professionals involved during the pre-construction stage of construction projects. Therefore, the Poke-Yoke concept has been developed by Shingo based on a similar principle that minimizing errors could increase production.

Accordingly, implementing Poka-Yoke could be highly beneficial in reducing the causes of variations in the context of the construction industry. In the global context, the Japanese principle, called Poka-Yoke, has been used to prove mistakes in various industries, including construction. Poka-Yoke has six principles (Shingo 1986, Shimbun 1988, McMahon 2016, Tommelein 2018, as cited in Tommelein, 2019). They are Elimination, Prevention, Replacement, Facilitation, Detection, and Mitigation. Mistake-proofing has been practised in various types of industry sectors. Several stages consist of the life cycle of the project. Correct mistake proofing is directly affected by the various stages of construction. Tommelein (2008) and Tommelein (2019) confirmed that Poka-Yoke is well matched to the construction industry because of its small-group production and mixed production systems, the lack of data, and the lack of time to track data processing. The advantage of this usage is to identify the defects in the existing situation and search for strategies to overcome the issues in the future. According to Tommelein (2008), Poka-Yoke needs to think about the manufacturing process and its components in different ways, but once professionals learn to identify the mistake-proofing process, their new thinking can find many opportunities to use workplace fault prevention. A suitable mistake-proofing method is proceeding without any manmade involvement (Sadri, Taheri, & Azarsa, 2011). Yet, Magdoiu and Oprean (2014) specified that human involvement in the method of mistake-proofing is acceptable for the construction industry. Therefore, it is necessary to first determine the benefits and barriers before implementing the Poka-Yoke to minimize variations in the Sri Lankan construction industry. However, there is a lack of research on the benefits and barriers of implementing Poka-Yoke to reduce variation in the Sri Lankan context. Therefore, the research aims to investigate the benefits and barriers of implementing Poka-Yoke to minimize variation in the construction industry. The objectives that followed were set to accomplish this aim: Benefits of implementing Poka-Yoke to minimize variation in Sri Lankan construction projects and barriers to implementing Poka-Yoke in Sri Lankan construction projects. In light of this, the next section provides a comprehensive review of the literature on the benefits and barriers of Poka-Yoke implementation for the construction sector. Thereafter, a research methodology will be discussed along with the research findings. Finally, the discussion and conclusion will be presented with the recommendations.

2. Literature review

2.1 BENEFITS OF POKA-YOKE IMPLEMENTATION TO THE CONSTRUCTION INDUSTRY

The objective of the Poka-yoke concept is to initiate a system that prevents defects and identifies defects' roots to prevent them from continuing through the system. Thus, Following Table 1 highlights the benefits of Poka-Yoke to the construction industry.

Table 1: Benefits of implementing Poka-Yoke

Benefits	Description	References
Assurance of continuous flow	It makes continuous flow by minimizing rework through error-proofing. Hence, keeping continuously flowing is important due to the construction industry has more activities that are interconnected to one another. Reducing important activities in the construction site does not a proper manner to make sure continuous flow. However, If the rework can be avoided, it is assured the product to flow properly.	(Maqbool, 2017), (Koskela 2000 as cited in Picchi & Granja, 2004), (Picchi & Granja, 2004)

	Hence, Poka-Yoke can be installed on the construction site, and machinery supplied on-site and avoiding incorrect use of these kinds of products.	
Improve client satisfaction	The employer does not satisfy if the final construction project is completed with a defect. Therefore, it is a possibility to make a product up to the level of client satisfaction through poka-yoke, which is no allowance to make a defective product within time, cost, and quality.	(Richard, Peter , & Gerryshom , 2015), (Burlikowska & Szewieczek, 2009)
Improve productivity	The users can easily understand and proceed with the Poka-Yoke principle due to its easiness, inexpensiveness, and smartness. Hence, Poka-Yoke can be easily suited for the construction industry by improving productivity.	(Burlikowska & Szewieczek, 2009), (Sadri, Taheri, & Azarsa, 2011)
Proper errors identification	Poka-Yoke can be used to avoid inadvertent errors and coordinate the workers to eliminate the mistake, as well poka-yoke does not allow jumping to the next step of the process with mistakes. If errors are identified in the error itself phase, the cost for reconstruction and time can be saved.	(Sadri, Taheri, & Azarsa, 2011)
Not focused on only one activity	can be applied to tasks, and operations on every scale, such as small and large construction projects and all construction industry sectors. Engineers' involvement does not require.	(Tommelein & Demirkesen, 2018)
Improve health & safety	The construction works are more complex and uncertain of work. Hence, the risk of possibly going through in the wrong manner is high and could be avoided through poka-yoke without threatening workers' safety and health.	(Sadri, Taheri, & Azarsa, 2011)
Less investment cost	It can be implemented at a minimal cost even though it requires investment in new product development. A highly cheap concept with high performance.	(Tommelein, 2008), (Saurin, Ribeiro, & Vidor, 2012)
Improve the quality level	The construction workers are free from doing repetitive work which gives them a chance to increase their ability to do the quality construction process through poka-yoke. Additionally, to get a quality product, the rework cost and product defects may be reduced.	(Sadri, Taheri, & Azarsa, 2011)
User-friendly to avoid mistakes	The workers in the construction industry cannot be considered a machine. While more mistakes may happen during working time: forgetting steps in a process, and assembling the wrong components in the process like. Then, the situation can be avoided through poka-Yoke. Furthermore, the Mistake-Proofing concept is friendly used in the architecture-engineering-construction.	(Binner, 1996 as cited in Magdoiu and Oprean (2014), (Tommelein, 2019)
Achieve less wastage	Waste is less, and energy usage is less, less removable are substantial benefits. Significant time is saved and increased capacity and flexibility.	(Dos Santos & Powell, 1999), (Sadri, Taheri, & Azarsa, 2011)
Easy way to identification	This incremental takes a unique form of defect, problem identification, solution application, and development.	(Dos Santos & Powell, 1999).
Quick respond	Once an error occurs, immediate action is required	(Burlikowska & Szewieczek, 2009)
Reduce additional effort	Reduce additional inspection time, cost, and quick action when identifying an error in the production period.	(Li & Liu, 2016)
Minimizing the possibility of occurring errors	Using Poka-Yoke principles, less frequency of errors	(Burlikowska & Szewieczek, 2009)

Considering all benefits mentioned above, Poka-Yoke is the principle that has more benefits and can be achieved through implementation. The user-friendly concept can be used to improve the productivity of output. When analyzing most of the benefits, such as continuous flow and client satisfaction mentioned in the past literature, those are related to identifying errors or mistakes in the construction industry. It does mean poka-yoke is a proper technique to identify the errors and mistakes in the construction industry, and its roots to gain more benefits as mentioned in the above table. However, yet in the Sri Lanka context, there has not been research regarding Poka-Yoke. Then, it is essential to identify the barriers when implementing Poka-Yoke principles, which are described below.

2.2 BARRIES TO IMPLEMENT POKA-YOKE IN THE CONSTRUCTION INDUSTRY

Poka-Yoke has been fundamentally approached in the production system, although there is only initial attention in the construction industry (Dos Santos & Powell, 1999). Lazarevic et al., (2019) have identified the barriers as investment cost is high, lack of responsiveness, lack of training on Poka-Yoke, fear to initiate due to a jobless mind, complexity, frequent design modifications, and high-cost investment including resources. Further, Tommelein (2018) enhanced the principles that are difficult to understand by reducing knowledge. Poka-Yoke does not have friendly manner homogeneity (Dos Santos & Powell, 1999). Sadri, Taheri, and Azarsa (2011) claimed that it was an ineffective and inappropriate method.

There is few research that has been carried out regarding the barriers to Poka-Yoke implementation. Hence, Koskela (1992) and Dos Santos and Powell (1999) explained that construction has a particular mix of peculiarities. Authors further claimed that these particularities have often been used to defend the distinction of construction from other industries. Thus, the development of construction concepts and techniques carries the risk of alienation and increases the difficulty of exchanging ideas with people from different industries.

In a similar attempt, Koskela (1992) studied the potential of applying the New Production Philosophy to construction. New Production Philosophy, which was first introduced in the 1990s has been called by several names, including lean production (Aziz & Hafez, 2013). On the other hand, Saurin, Ribeiro, and Vidor (2012) identified the Poka-Yoke concept has also been identified as a lean production practice tailored to eliminate the production of defective parts. Therefore, both poka-yoke and New Production Philosophy share common traits being derived from the production sector. Hence, the problems and barriers identified by Koskela (1992) could have a similar impact on the implementation of poka-yoke in the construction industry.

Koskela (1992) also explained that such durability and expensive construction features are not treated as related in this context. Moreover, the complicated and uncertain nature of construction (Ilyas, Li, & Ullah, 2019; Oladapo, 2015) is shared by many other industries, which are considered as resulting process features than as primary peculiarities. Koskela (1992) stated that there are procedures in manufacturing that were established well and useful manner. Further, if these procedures are not implemented in construction, the following reasons in the table that are often available as reasons. Table 2 presents a summary of the problem identified by Koskela (1992), Tatum and Nam (1988), and Warszawski (1990) concerning the adaption of new concepts in the production sector to the construction industry.

Table2: Barriers to implementing Poka-Yoke in the construction industry.

Peculiarity	Process control problems
One-of-a-kind product	• Production cost is high. Hence, the feedback cycle does not fulfilled. • The next stages of the project are obstructed, and it is prevented from flowing smoothly if the omission and correction have occurred in previous stages. • Coordination of uncertain activities
Site production	• Variability problems: There is no security from elements or interference • Complexity problems: Coordinate the spatial flow of the workplace • Transparency problem: The work environment is constantly evolving and making layout design difficult.
Temporary multi-organization	• Communicating data, knowledge, and design solutions across organizational borders • Reaching goals collectively through the project organization
Regulatory intervention	• Authority involvement. • Getting approval for design solutions is often unexpected. • Authorities take time for checking and it causes delays.

According to the above factors, through Poka-Yoke's implementation in the construction industry, it can be identified some barriers that have to be faced. When analysing the barriers that were highlighted in the past literature, those are related in a common manner. However, implementing Poka-Yoke is not an easy activity among stakeholders.

3. Methodology

A literature survey was carried out by reviewing relevant literature that was books, research papers, unpublished dissertations, and journal papers to gain knowledge about the benefits and barriers of Poka-Yoke. Comparative to a quantitative technique, qualitative research is better suited to evaluate alternatives, uncover novel ideas, and diagnose a situation when there is limited knowledge about the phenomena or topic (Antwi, & Kasim, 2015; Maxwell, 2013). According to that, this research used a qualitative research approach, which may be thoroughly analysed based on the research problem. The research technique decides how the data collection method and data analysis method was implemented. Hence, the research technique is broadly divided into two main categories as data collection techniques and data analysis techniques (Yin, 2009). A typical technique for gathering data in qualitative research is semi-structured interviews, which combine closed- and open-ended inquiries and usually include follow-up why or how questions in order to elicit reliable data and in-depth opinions from respondents (Adams, 2015; Kallio, Pietilä, Johnson, & Kangasniemi, 2016). Based on the qualitative research approach, semi-structured interviews were conducted to collect qualitative data, which was analysed using code-based content analysis through NVivo 12 analysis techniques to determine the benefits and barriers for implementing Poka-Yoke to minimize variation in the construction industry.

Purposive sampling is a non-random technique that is frequently used in qualitative research to identify and select individuals or groups of individuals who are proficient and knowledgeable about a phenomenon of interest (Etikan,

Musa, & Alkassim, 2016). The further author stated that the technique seeks out individuals who can and are willing to share the information through their experience or knowledge. On the other hand, willingness to participate, availability, and the capacity to express perspectives and experiences are crucial in addition to knowledge and experience. Accordingly, ten industry experts were selected, who are having more than 13 years of experience in the construction industry and variation and having knowledge of Poka-Yoke, using purposive sampling as presented in Table 3.

Table 3: Profile of the experts

Experts	Designation	Experience in the construction project	Awareness about variations		Awareness on Poka-Yoke
R1	Chartered QS	22	Consultant, Contractor	Well aware	Well aware
R2	Engineer	16	Consultant, Contractor	Well aware	Aware
R3	Chartered QS	22	Client, Consultant, Contractor	Well aware	Aware
R4	Chartered QS	22	Consultant, Contractor	Well aware	Well aware
R5	Senior Architect	13	Client, Consultant,	Well aware	Aware
R6	Chartered QS	22	Client, Consultant, Contractor	Well aware	Aware
R7	Project Manager	18	Client, Consultant, Contractor	Well aware	Well aware
R8	Engineer	15	Consultant, Contractor	Well aware	Aware
R9	General Manager	24	Consultant, Contractor	Well aware	Well aware
R10	Engineer	20	Consultant, Contractor	Well aware	Aware

The tenth interview marked the point at which there was no more new data to be collected, signalling data saturation. Additionally, to capture all the perspectives on the parties who generate variations, Client, Consultant, and Contractor perspectives were chosen to participate in the interview.

4. Research findings

4.1 BENEFITS OF IMPLEMENTING POKA-YOKE TO MINIMIZE VARIATION IN THE SRI LANKAN CONSTRUCTION PROJECTS

Based on the expert's opinion, there are many benefits of implementing mistake proofing to minimise variations in the construction industry as presented in Table 4.

Table 4: Benefits of implementing Poka-Yoke in the Sri Lankan construction project.

No	Benefits	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R10
1	Minimizing time overrun	X		X	X	X		X		X	X
2	Minimizing cost overrun		X	X	X	X			X	X	X
3	High productivity		X				X		X		
4	High quality		X				X		X		
5	Elimination of waste product	X		X			X	X		X	
6	Less overhead cost to the contractor		X	X	X	X			X		
7	Easy adaptation	X		X			X	X		X	
8	Improve the site safety	X			X		X	X			X
9	Improve the relationship between parties			X						X	
10	Maintain good communication		X			X			X		
11	Using any type of construction	X			X			X			X
12	Smooth work progress	X		X			X	X		X	
13	Sustain the performance	X	X		X				X		X
14	User friendly	X				X		X			
15	Less rework and demolition		X	X			X		X	X	

The majority of experts' common opinion on the benefits was minimizing cost increment, on-time completion, improvement of quality, and production cost increases. Additionally, the construction industry has a special feature, which is the high possibility of adapting to new technology. The construction industry is demanded to follow new methods and the latest products with evolving technologies and innovative products or various services providers and manufacturing industries. Further, Poka-Yoke is also a new technique to be applied in the construction industry. Hence, one of the questions that were asked was *"why this_principle cannot apply to other related activities in the construction industry like safety procedures and tendering procedures".* R6 and R10 pointed out *"considering safety issues in a real manner, they highlighted that more safety issues arise due to the mistakes. However, there was no proper safety precaution system in the industry to overcome the mistakes. If it is possible to introduce these techniques to the industry, the occurrence of safety issues can also be minimized"*.

Accordingly, R3 stated that *"variations can be identified as the results of non-value-adding activities in the design stage. Hence, it is required to eliminate the non-value activities in the pre-contract stage itself. Then, it helps to make the flow smoothly and the project goes smoothly in the construction stage".* Further, R2, R8, R9, and R10 identified the benefits as minimizing time overrun, cost overrun, improving quality of the construction projects. R1 stated that *"before starting the design, the end-users requirement also can be identified through Poka-Yoke principles. Then the projects can be completed without any variations in the construction stage. So, the parties can improve the relationship and there no disputes cases among parties. Further, the employer gets the anticipated value for money".* R1, R4, R7, and R10 emphasised *"these Poka-Yoke principles can be adopted any type of construction".*

R1 pointed out the elimination of waste products, easy adaptation, and sustain performance as the benefits. R3, R4, and R8 expressed *"Considering the employer's point of view, not occurring variation is the additional saving to the employer, whereas it would be the less overhead cost to the contractor".* Even though the benefits were identified, there were barriers to implementing the Poka-Yoke principles in the construction industry. It describes in the next subsection. In light of this, the findings of the research identified fifteen benefits to implement Poka-Yoke for minimising variations in Sri Lankan construction projects.

4.2 BARRIERS OF IMPLEMENTING POKA-YOKE TO MINIMIZE VARIATION IN THE SRI LANKAN CONSTRUCTION PROJECTS

Since Poka-Yoke was initially practiced in numerous industries, it is not impossible to adopt it in the construction industry easily. However, there are some challenges for mistake-proofing to be implemented in the Sri Lankan construction industry. Further, R2 highlighted that the same barriers of lean construction would be applied to the Poka-Yoke implementation. Hence, a summary of all identified barriers is shown in Table 5 below.

Table 5: barriers to Implementing Poka-Yoke in the Sri Lankan construction project.

No	Barriers	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
1	Lack of awareness	X				X		X			
2	Work pressure		X				X		X		
3	Lack of understanding			X	X					X	X
4	Fear to apply		X		X		X		X		X
5	High initial capital	X	X					X	X		
6	Not preferable to change the traditional way			X		X				X	
7	Lack of industry support	X		X		X		X		X	
8	Taking more time for getting the result	X			X		X			X	
9	Lack of training	X	X			X	X			X	

According to R1, R4, R5, and R7, lack of awareness, lack of expertise, and lack of professional knowledge are the main barriers in the construction industry. R2 expressed the opinion from the consultant's perspective *"If these principles are applied to certain construction projects to minimize the variations, there is more time consuming for evaluation of the result whether it would be a success or not because generally, construction projects take more time to complete. Further, if the results are not in an expected manner, then it becomes a time waste. That's why the expert is fear to implement these principles in advance since these are new techniques for the construction industry. All the experts have to wait until the implementation is well-matured in the construction industry".* Based on the R2 explanation, two significant barriers were highlighted, which are time barriers and fear of implementation.

Another challenge identified during the interviews is the lack of professionals in construction to implement Poka-Yoke as per the comment by R3, R7, and R9. However, R5 clearly stated that "though there are competent professionals in the industry, they have less awareness about the mistakes proofing. For example, the client expects to take over the project in advance to get more benefits. Most of the time, few persons are allocated to design a particular project. The design team consists of less than ten persons with limited *time before the commencement of the construction works. Then, they disagree to change the normal working style in the designing stages".* Therefore, lack of awareness and changing the traditional way of working were identified as barriers to poka-yoke implementation. Adding to further barriers, R6 stated that Lack of training on the Poka-Yoke principles because these are new techniques to the construction industry. Accordingly, the results of the investigation demonstrated nine barriers of implementing Poka-Yoke to reduce variations in Sri Lankan construction projects.

5. Discussion

Figure 1 demonstrates the benefits and barriers of implementing Poka-Yoke to minimise variation in the construction industry. To ascertain whether these literature findings were appropriate for the Sri Lanka construction project in general and particularly for minimising variations in the construction project, validation was carried out. Accordingly, the blue colour lines in the figure represent findings from the literature review. Pink colour lines in the figure represent the findings from expert interviews, and green colour lines represent data from both expert interviews and literature reviews.

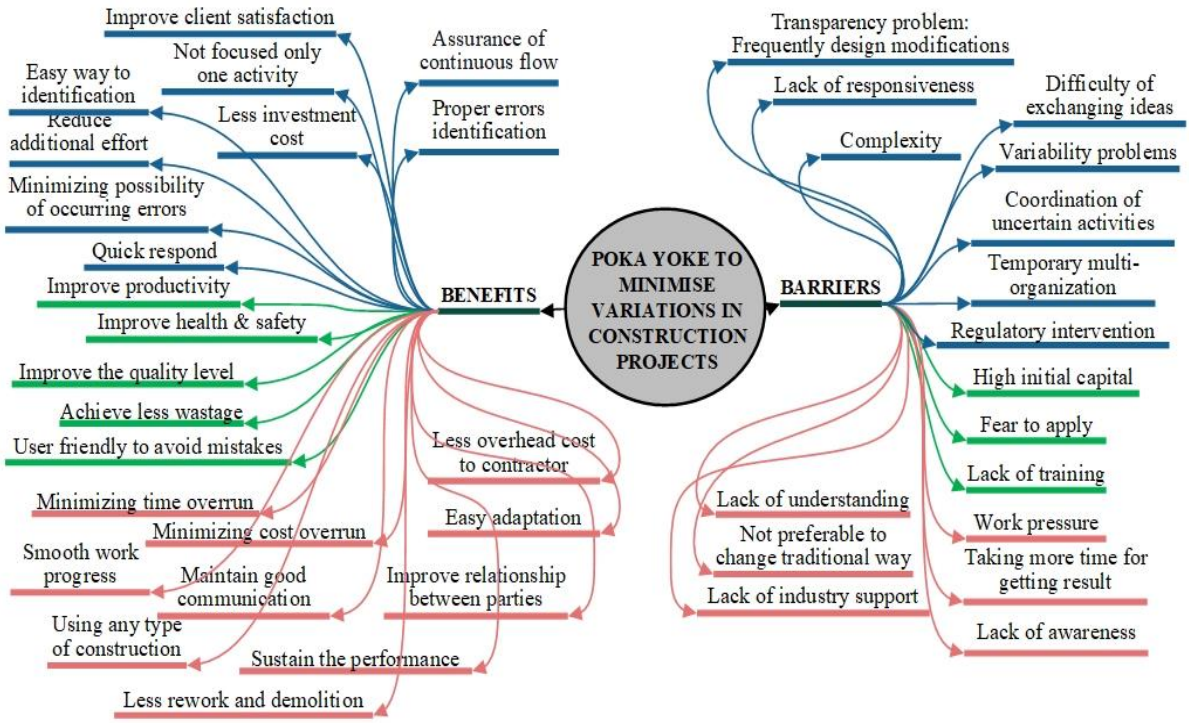

Figure 1: Summary of benefits and barriers of Poka-Yoke implementation to minimise variations in Sri Lankan construction projects

The variations during the post-contract stage have a multifaceted impact on projection performance. According to Jawad, Abdulkader, and Ali (2009) cost overrun due to variations is estimated to be 5-10% of the original contract value and time for completion, less than 10% of the initial contract period. Additionally, variations may affect various other impacts in construction projects such as claims, disputes, and conflicts between the parties (Fernando, 2009). Although there are terms related to variations in the used standard forms, there is no proper mechanism that has been introduced to minimize the variations. However, there has not been a mechanism to mitigate the causes of the variation during the design stage of the Sri Lankan construction context. The Poka-Yoke principle from Japan has been applied globally to demonstrate mistakes and errors in a variety of industries, including construction. Accordingly, the study aims to look into the benefits and barriers of implementing Poka-Yoke to reduce variation in the construction industry.

Identified benefits in the literature review were maintaining high productivity, maintaining high quality, using any type of constructions, identification of errors properly, improving health and safety, user friendly to avoid mistakes, and minimizing additional effort (Burlikowska & Szewieczek, 2009; Dos Santos & Powell, 1999; Picchi & Granja, 2004; Sadri, Taheri, & Azarsa, 2011; Tommelein, 2008). Additionally, all the above benefits identified through the literature review were confirmed through the experts' interviews and it is pertinent to the Sri Lanka context. Furthermore, some experts emphasised that minimizing cost overrun, minimizing time overrun, less rework and demolition, minimizing the obstruction to work progress, improving the relationship between the parties involve for the variations directly or indirectly, keeping the project performance in the expected manner having the win-win approach and in line with the project objectives as added benefits for implementing Poka-Yoke in the Sri Lankan construction industry. Some benefits identified through the literature review such as less investment cost, and reduce additional effort were not acknowledged by the experts. As a result, these benefits are not applicable when employing Poka-Yoke for minimising variations in construction projects in Sri Lanka.

As emphasized through the literature review, Dos Santos and Powell (1999) and Lazarevic et al. (2019) highlighted the barriers such as lack of responsiveness, lack of training on Poka-Yoke, fear to initiate due to jobless mind, complexity, frequent design modifications, high-cost investment including resources, the difficulty of exchanging ideas with people from other industries. During the literature review, some of the identified barriers were confirmed through the expert interviews such as lack of training on Poka-Yoke, fear to initiate due to a jobless mind, and high-cost investment including resources. The experts did not recognise a number of the barriers that the literature analysis found, such as transparency problems: frequent design modifications, lack of responsiveness, complexity, the difficulty of exchanging ideas with people from other industries, variability problems, coordination of uncertain activities, temporary multi-organization and regulatory intervention. Thereby, while using Poka-Yoke to minimise variation in the construction project in Sri Lanka, these barriers are not relevant. Moreover, when considering the variation context, experts newly added some barriers such as work pressure, lack of awareness, lack of understanding, reluctant to change the traditional method, lack of industry supports, taking time to evaluate the results, waiting until the project is completed to evaluate the results and lack of specialists. Accordingly, research

findings revealed fifteen benefits that will motivate practitioners to employ Poka-Yoke to minimise the causes of variations in Sir Lankan construction projects and nine barriers to Poka-Yoke implementation.

6. Conclusion

The research was to identify the benefits of implementing Poka-Yoke to minimize variations in the construction industry. Consequently, numerous benefits were identified through the expert's interview and the literature that are pertinent to the Sri Lankan context. Minimizing cost overrun, minimizing time overrun, improving a relationship between parties, less time to rework, high productivity and quality, user-friendly to avoid mistakes, eliminating waste products, sustaining the performance, and smoothly progressing are the main identified benefits. Furthermore, the elimination of waste products is beneficial to overcome the impacts on the environment and human health. If the project can be completed within the anticipated time and cost, the employer can earn proper value for the money incurred for the construction. If there are no variations in the projects, the parties can work in a collaborative manner, which helps to succeed in the projects. Investigating the barriers to implementing Poka-Yoke in the construction industry was another objective of the research. The main barriers were identified through literature synthesis considering the global context. Moreover, most of the barriers were confirmed during the expert interviews. The main barriers are work pressure, lack of awareness, fear of applying, lack of training on Poka-Yoke, fear of changing the traditional method, lack of understanding, and more time to evaluate the results. Accordingly, the study's findings showed fifteen benefits and nine barriers to implementing Poka-Yoke to minimise variations in Sri Lankan construction projects.

However, the professional has to wait until the end of the project to evaluate whether the results of Poka-Yoke have reached the anticipated level. This research has opened up many research arenas in the area of Poka-Yoke implementation for the construction industry. More in-depth studies are required to confirm the applicability of this concept to the Sri Lankan construction industry. The findings of the investigation can be seen as the first step for other developing nations performing research projects of a similar nature as it theoretically completes the vacuum in the literature that exists regarding the benefits and barriers for Poka-Yoke implementation to minimise variations in construction projects. The research was limited to the construction project in Sri Lanka. Further, due to time and geographical limitations, the data was collected from construction projects in Western Province. This excludes civil engineering construction projects to minimize the complexity which may arise in the future when comparing both kinds of projects simultaneously. Accordingly, the results of this study would also be relevant to other emerging nations with geographically comparable regions to Sri Lanka's western region. Thus, this study will promote further research into the strategy for overcoming barriers to Poka-Yoke implementation to minimise variations in construction projects as well as the practical implications of Poka-Yoke implementation to minimise variations in construction projects.

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