

Development of Poka-Yoke Solutions of Sustainable Antifragile Agile Lean (SAAL) Supply Chain Control Tower Systems in the Construction Industry of Iran

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ABSTRACT

The construction supply chain is complex. This complexity causes problems and errors. In Iran, due to an anarchic atmosphere, it is very common for problems and errors to occur. The Sustainable Antifragile Agile Lean (SAAL) supply chain was designed to deal with these conditions. One of the widely used tools in this supply chain is the use of information systems such as the control tower. But these systems may also have errors. The main purpose of Poka-yoke is to make mistakes impossible. Therefore, in this research, the main dimensions of Poka-yoke solutions are categorised based on previous research and then experts' opinions are collected with the help of a questionnaire tool. In order to prioritise the factors based on control tower systems, the best-worst method was used. The results showed factors such as proper planning of quality management programs, building information modeling and proper implementation of the productivity cycle is the most important.

Keywords: Supply Chain, Sustainable Antifragile Agile Lean, Control Tower, Poka-Yoke

Introduction

Poka-yoke was first proposed by Shigeo Shingo. This concept was widely used in Toyota's production processes, which led to great changes in quality improvement in this company and then in the world. Poka-yoke is a set of interdependent actions that help the organisation to prevent the waste of resources as well as energy and time before errors occur. Poka-yoke has created methods and techniques that try to eliminate human factors when doing something that requires memory, attention and concentration due to repetition. Of course, this does not mean eliminating thinking and the role of humans in doing things. Rather, it tries to free people's time and mind through it, and by creating a creative system, activities can be done correctly without fear of making mistakes (Widjajanto et al., 2020).

With its simple rules, Poka-yoke, in addition to leading to many savings, creates conditions that even if the user is not in normal conditions, he cannot make a mistake and this ultimately prevents any waste, rework, waste and accidents (Valamede & Akkari, 2020). Poka-yoke is based on the principle that most incidents are caused by human error. This does not mean that mistakes should not occur, because mistakes are caused by many factors that result in the occurrence of various human errors. Poka-yoke is focused on providing solutions that reduce human errors as much as possible in repeatable work processes so that the forces can be focused on creative behaviours and functions. Although this technique has found many uses in manufacturing industries (Widjajanto et al., 2020). But in the field of construction, it has been paid less attention.

Today, in the age of technology, construction companies have moved towards updating their information systems

and developing their information systems in order to speed up and ease their work. Among these systems are building information modelling, business intelligence and other Industry 4.0 technologies such as the Internet of Things and the control tower (CT) (Widjajanto et al., 2020).

On the other hand, with the ever-increasing complexity of work, the pressures caused by the workload, economic problems, the reduction of expert forces and the increase in competition in the Iranian market, Iranian companies have faced many errors and mistakes in the course of their activities (Romero et al., 2022). This issue has caused them to be somewhat skeptical when confronting new technologies. This problem is extremely high in the construction industry, especially in its supply chain, due to the existence of many stakeholders, diverse works and many work environments.

Therefore, today, Iran's construction industry managers are worried that new technologies will have a negative impact on work performance or the satisfaction of stakeholders. They are concerned about whether new technologies can be compatible with previous systems and can work effectively without any mistakes, and whether their employees can afford to use them. Considering the many problems faced by construction companies in Iran, can these systems help them in reducing mistakes and errors?

On the other hand, nowadays, the construction industry's intelligentisation is a process that is being learned as one of the main strategies. In this strategy, almost all the important working relationships of the organisation with customers, suppliers and employees are possible in a smart way. Also, the main business processes are carried out through virtual networks, which cover the entire organisation or connect several organisations (Romero et al., 2022).

In such a complex ecosystem where organisational processes are formed on the basis of information

technology and data and information has a special place. The role of developing Poka-yoke solutions in the information system such as the supply chain CT in construction projects that works as the core of the organisation's business—it should be considered by managers so that organisations can increase the satisfaction of employees and stakeholders and gain more market share.

Since CT systems, as a powerful tool, provide the possibility of communication between the needs of employees and beneficiaries and the services provided to them, their errors and defects can have irreparable effects on attracting, maintaining and loyalty of users.

Therefore, in this research, Poka-yoke solutions of supply chain CT systems have been considered as a main strategy of the construction industry. Also, since each of the Poka-yoke solutions requires spending a lot of time, energy and money, it is inevitable to prioritise these solutions for the senior managers of the organisation; therefore, the aim of this research is to develop solutions to make CT systems fail-proof in the supply chain of Iran's construction industry. For this purpose, after examining and researching the desired errors, they are extracted and presented to the experts in the form of a questionnaire (made by the researcher), which is selected and approved by using nominal group techniques. After confirming the validity of the questionnaire experts in the field of information technology, the obtained information is analysed based on the steps of the research method, including the weighting of criteria by the best-worst method, prioritisation, and final validation of the model. The structure of the article is presented in Fig. 1. As seen in the figure the article contains five sections covering the Theoretical Foundations, Methodology, Result, Conclusion and Future research and Limitations. In the next section, Theoretical Foundations and criteria poka-yoke in information systems are presented.

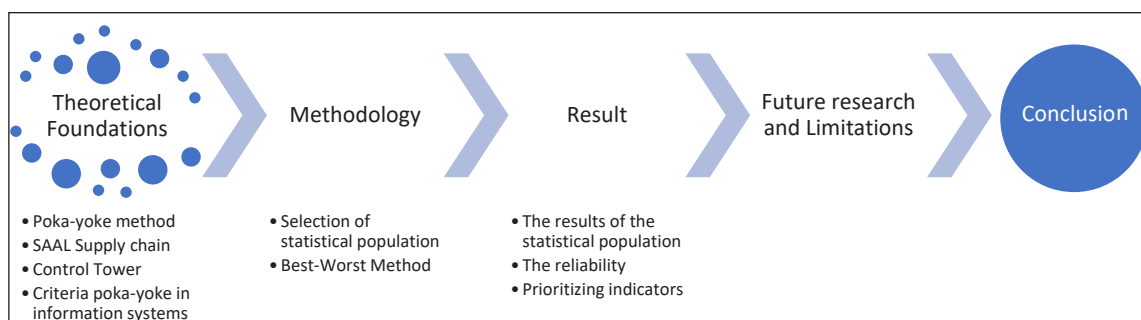


Fig. 1: The Structure of the Article

Theoretical Foundations

Poka-Yoke Method

Poka-yoke systems automatically stop the work process and thus prevent errors from occurring in abnormal conditions. These systems have two basic functions; the first function is 100% control, which means it creates the ability to identify non-conforming items completely in the system. The second function is to perform control and inspection in such a way that if abnormalities occur,

they can give feedback and take immediate action. This method is more effective because it is combined with controlling the main root of the problem. As a result, it prevents mistakes caused by defects, and in general, it can be defined as a means or intermediary that prevents errors from causing defects (Romero et al., 2022; Widjajanto et al., 2020).

Huuskonen (2020) presented a dynamic model to evaluate the Poka-yoke effect in a production system. The results of their modelling showed that when a mistake occurs in the process, one of the following four consequences occurs (Fig. 2) (Huuskonen, 2020).

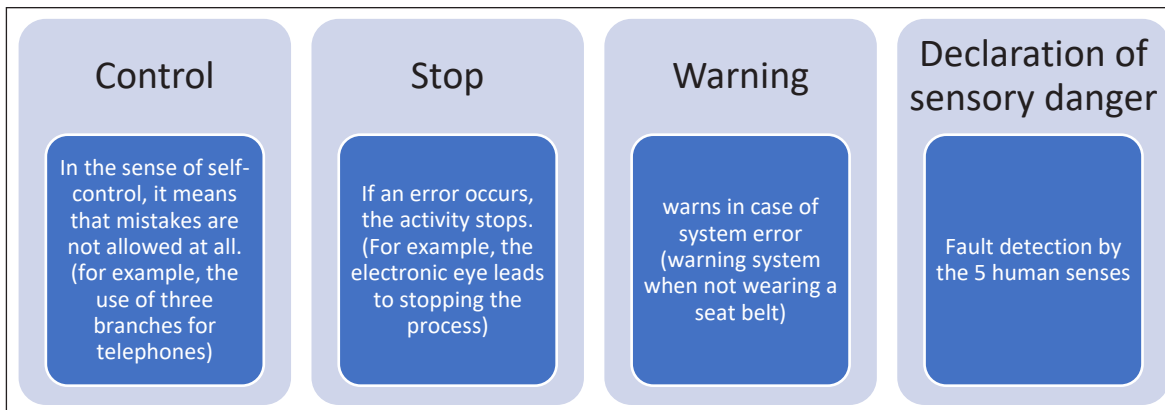


Fig. 2: Four Consequences of a Mistake in the Process (Huuskonen, 2020)

Poka-yoke systems use sensors or control tools in the process to detect errors that may be hidden from the operator's view. A warning system alerts the operator to stop the machine or track down the problem. If the Poka-yoke system is used in source inspections, it prevents mistakes before the process produces a defective part (Huuskonen, 2020).

This system adjusts the process with two methods to prevent errors in the process; in a control system, when an irregularity occurs, it stops the tool or locks a clamp on the part and prevents its movement. The purpose of this method is to eliminate or reduce human errors in production and management processes as a result of human mental and physical abnormalities (Huuskonen, 2020). In fact, it eliminates independent errors. The main idea of this method is to prevent the causes that may be used by mistakes and to use a relatively cheap control system to determine the compatibility of the product with the model (Romero et al., 2022).

Preventing defects in the process before they occur is the best way to reduce waste and thus reduce costs. The poka-yoke system includes three main methods of communication, counting and movement sequence,

each of which can be used in a control and warning mechanism. An approach that uses automatic tools or methods to prevent simple human and machine errors (Rubio-Romero et al., 2019; Widjajanto et al., 2020).

The origin of these errors can be a lack of understanding of issues, forgetfulness, errors in identification, lack of experience and concentration, delays, arbitrary errors, unintentional errors, errors related to slowness in reaction, accidental errors, intentional errors, etc. The Poka-yoke concept is widely used not only in product and process design but also in order to reduce defects (Lazarevic et al., 2019). There are different types of Poka-yoke, one of the main methods of which is to focus on training employees and gutturalizing operational instructions. For example, if someone is working on an assembly line and is rotating between three different parts, they may suddenly get confused about which part is next. Therefore, there must be a digital sign with a suitable perspective so that it can be seen clearly and not be mistaken (Lazarevic et al., 2019).

The large number of variables in a process creates many opportunities for errors. Among these variables, we can refer to weak or inappropriate guidelines and standards,

equipment, and devices, non-compliant raw materials, wear and tear of tools and also human errors (Martinelli et al., 2022).

SAAL Supply Chain

The construction supply chain is very complex due to the short-term thinking of construction projects, the existence of multiple stakeholders, and diverse and changing tastes. Due to the existence of non-specialists in Iran's construction industry, and Iran's economic, social, political and environmental crises, the management of construction projects is very difficult. This causes to make types of conditions of anarchy/chaos and black swans. Therefore, it is very difficult to manage its supply chain, and needs to be reconsidered all of the approaches (Sadeghi et al., 2022).

Now, in the post-COVID-19 era, and with the current crisis intensifying, leaders in the construction industry must take a new look at the issues. A positive view of the crisis in order to accept and exploit it, instead of confronting it (Hill et al., 2021; Sadeghi et al., 2022).

Therefore, as Greene (2010) said at a time when Project/Organisation is in a critical situation on the one hand, and on the other hand, is in a position of weakness and defense, due to the lack of resources, more efficient methods should be used, any of the previous approaches (project management, agile, flexible, resilient, lean, and sustainable) are not responsive in such conditions (Greene, 2010; Sadeghi et al., 2022).

It is true that each of these approaches alone has useful features, but their capabilities are not enough to deal with the diverse conditions of the construction environment (Soheil Sadeghi et al., 2022). Therefore, in conditions, such as the conditions of Iran, which has many crises, innovative approaches should be used in new dynamic ways (Greene, 2010). Because these approaches only try to resist the problems and may not even be responsive. Therefore, it is necessary to take advantage of new approaches or use existing approaches in a new way that, in addition to being flexible and resilient against the conditions, take advantage of these conditions and become stronger (Tembo & Nicholas Taleb, 2012).

The Sustainable Antifragile Fragile Lean (SAAL) strategy is a supply chain strategy, an Antifragile value-creating efficient paradigm in the construction industry to face such anarchy/chaotic conditions. SAAL supply chain strategy is based on the need for knowledge of the construction supply chain to know who, where, and when

is doing what action on the project into the supply chain block. The data collected from the supply chain process is the basis for influence process management (Soheil Sadeghi et al., 2022). SAAL strategy, in line with the words of Nassim Taleb and W. Chan Kim, by exploiting agile, lean, flexible, resilient, and sustainable approaches, tries to benefit from crises in addition to responding appropriately to the conditions. In this strategy, an attempt is made to create value by obtaining accurate information and with the help of leverage of turning points and co-creation. According to Sadeghi et al.'s (2021) statements, exchanges between SAAL supply chain approaches can help construction supply chains and ultimately their organisations to become more efficient, simpler, and more sustainable. They state that the differences between these approaches lie in their focus, but they aim to improve conditions in different ways (Sadeghi et al., 2022).

Control Tower

An information system like a neural network should be located in the heart of a supply chain in order to create integrity and flexibility. This information system should be a collection of software, hardware and generally connected components (Ivanov & Dolgui, 2021). Because it is able to collect, retrieve, process, store, distribute and index information to support the decision-making process as well as control a business. Also, the existence of coordination and control in this system helps employees to better analyze problems and perform complex issues and provide services more effectively (Dalenogare et al., 2018; Mastos et al., 2020).

The main activities performed in this system are based on three elements of input, processing and output of that system (Mrugalska & Wyrwicka, 2017). The input of a system is raw data that is absorbed and collected within the organization or from its external environment (Midkiff, 2021). Processing is the step that transforms this raw input into a meaningful form. The output conveys the processed information to the people who will use it or the activities for which this information will be used. This system enables the organisation to increase its income or reduce its costs by providing information that helps managers to make better decisions (Ivanov & Dolgui, 2021).

This system in the construction industry consists of Building Information Modeling, Internet of Things, Global Positioning System, blockchain, cloud processing, databases, artificial intelligence, business intelligence, etc. which can eventually form a CT.

The Supply chain CT as an information system in the era of Industry 4.0 is actually a supreme decision-making centre that facilitates execution at levels that cannot be easily managed by humans by creating a coordinated network, and continuous management of complexity. Therefore, basic capabilities must be provided in this system to enable visibility and awareness levels to achieve this mission (Midkiff, 2021; Sharabati et al., 2022).

In general, a CT acts as a command centre to enable a company to engage closely with suppliers and be more proactive in providing customer service, ultimately reducing waste and improving profitability (Vlachos, 2021). Overall, a CT should provide a win-win situation throughout the supply chain, enabling the supplier

and other players to perform at optimal levels. For this purpose, there are many prerequisites for implementing a CT solution. Among these things are visibility and the number of floors required according to the cost and importance of the products, and how to manage them (Gerrits et al., 2022; Ye et al., 2022).

Considered Criteria Related to Poka-Yoke in Information Systems

The Table 1 has been collected and categorised as a summary of the criteria related to Mistake-Proof in information systems according to the relevant literature review.

Table 1: Criteria Poka-Yoke in Information Systems

#	The Main Criterion	#	Sub Criteria	Reference
C1	Quality management	C1.1	Proper planning of quality management programs	(Huuskonen, 2020; Lazarevic et al., 2019)
		C1.2	Skilled staff, advanced facilities, and equipment	(Jiménez, 2013)
		C1.3	Identification and management of operations	(Huuskonen, 2020; Kozikowski et al., 2022)
C2	Technological capability and innovation	C2.1	Design capability	(Lazarevic et al., 2019)
		C2.2	Building Information Modeling	(Ivanov & Dolgui, 2021; Rubio-Romero et al., 2019)
		C2.3	Development of all types of databases and business intelligence	(Jiménez, 2013; Romero et al., 2022)
		C2.4	Cabin resource management/war room techniques	(Sadeghi, 2022; Sadeghi et al., 2022)
		C2.5	Modular information systems	(Rubio-Romero et al., 2019)
		C2.6	Decentralized integrated information system	(Martinelli et al., 2022)
		C2.7	Technical ability	(Martinelli et al., 2022; Valamede & Akkari, 2020)
		C2.8	Proper implementation of the productivity cycle	(Ivanov & Dolgui, 2021; Widjajanto et al., 2020)
C3	Identifying human errors	C3.1	Inspection by camera	(Ivanov & Dolgui, 2021)
		C3.2	Use the controller	(Jiménez, 2013)
		C3.3	Use of a warning system	(Lazarevic et al., 2019)
		C3.4	Identification and management of human errors	(Kozikowski et al., 2022; Rubio-Romero et al., 2019)
C4	Increasing the capability of personnel	C4.1	Personnel training	(Martinelli et al., 2022; Valamede & Akkari, 2020)
		C4.2	Periodic visits to employees' work	(Rubio-Romero et al., 2019; Widjajanto et al., 2020)
		C4.3	Periodic tests of employees	(Ivanov & Dolgui, 2021; Romero et al., 2022)
C5	Employing work groups	C5.1	Rights/Benefits of stakeholders	(Kozikowski et al., 2022; Lazarevic et al., 2019)
		C5.2	Respect policies and laws	(Martinelli et al., 2022)
		C5.3	Social criteria of employees	(Ivanov & Dolgui, 2021)
		C5.4	Supervision of employees	(Huuskonen, 2020; Jiménez, 2013)

#	The Main Criterion	#	Sub Criteria	Reference
C6	Identify problems	C6.1	Eliminating the root causes of the error	(Jiménez, 2013)
		C6.2	Improvements in the intrinsic dimension of data	(Martinelli et al., 2022; Rubio-Romero et al., 2019)
		C6.3	Provide periodic reports	(Kozikowski et al., 2022)
C7	Management and organizational capabilities	C7.1	Empowering employees and management support	(Lv et al., 2022; Widjajanto et al., 2020)
		C7.2	Periodic capacity and facilities	(Ivanov & Dolgui, 2021; Martinelli et al., 2022)
		C7.3	Research and Development	(Valamede & Akkari, 2020)
		C7.4	Using problem-solving approaches	(Valamede & Akkari, 2020; Widjajanto et al., 2020)
C8	Updated systems	C8.1	Periodic updating of systems	(Kozikowski et al., 2022)
		C8.2	Improvements in data display	(Martinelli et al., 2022)
		C8.3	Improvement in the contextual dimension of the data	(Jiménez, 2013)
		C8.4	Continuous updating of the data generation process	(Lazarevic et al., 2019; Martinelli et al., 2022)
C9	Increase the safety of the work environment	C9.1	Improvement in ergonomics	(Haddud & Khare, 2020; Lv et al., 2022)
		C9.2	Improving the work environment	(Haddud & Khare, 2020; Lv et al., 2022)
		C9.3	Improvement of equipment	(Haddud & Khare, 2020; Lv et al., 2022)
		C9.4	Cultural development	(Jiménez, 2013; Romero et al., 2022)
		C9.5	Equipment maintenance	(Martinelli et al., 2022)
		C9.6	Insurance and facilities	(Ivanov & Dolgui, 2021)
		C9.7	Identify occupational hazards	(Kozikowski et al., 2022)
C10	Use of experiences	C10.1	Long term relationships	(Huuskonen, 2020; Valamede & Akkari, 2020)
		C10.2	Reputation and credibility of suppliers	(Lazarevic et al., 2019; Widjajanto et al., 2020)
		C10.3	Use of knowledge and experience	(Huuskonen, 2020; Rubio-Romero et al., 2019)
		C10.4	Use of past records	(Valamede & Akkari, 2020)
		C10.5	Communication systems	(Jiménez, 2013)
		C10.6	Reputation and credibility of the product in the market	(Martinelli et al., 2022) (Ivanov & Dolgui, 2021)

Since the supply chain control tower of construction projects as a powerful tool provides a communication bridge between suppliers and users and customers, the needs and services provided to them, errors and defects in it can have irreparable effects on the attraction, retention and loyalty of users. Therefore, in this research, the solutions to make the SAAL supply chain control tower fail-safe for construction projects as a case study, have been considered as a main strategy of the organisation. Because when implementing any system or approach, user acceptance and satisfaction are considered important criteria for determining the success of implemented systems. User acceptance is often the key factor in the success or failure of a project, and a lack of user acceptance for a long time hinders the success of new information systems.

Methodology

A consistent relationship can be seen between providing too much and insufficient information. On the one hand, too much information can make diagnosing a situation a bit like looking for a needle in a haystack, while too little information risks missing something important and relevant. So, without a long-term strategy—it is impossible to get decisions. Therefore, it is very important to choose the right indicators and then choose the right functions. This type of thinking is called a goal, question and metric. In the first phase, with the help of performance indicators presented in Table 1, a questionnaire is designed to determine the most important indicators. The top five indicators are determined in order to focus on the

Mistake-Proof solution of the control tower system. Then the desired functions for those indicators are described according to the opinion of experts.

Selection of Statistical Population

The statistical population of this project is the experts of Tahseen Company and the employers of the mentioned projects.

Best-Worst Method

According to the criteria and sub-criteria of sustainable supply chain performance (Table 3), a questionnaire is designed by the best-worst method and evaluated by experts. The best-worst method is one of the new multi-criteria decision-making methods introduced by Rezaei (2015). But human qualitative judgments usually have

ambiguous features and do not have standard information in the real world. Therefore, Zhao et al (2017) created the fuzzy best-worst method. In their research, they said that the usage of fuzzy numbers eliminates ambiguities in the respondent's speech. The best-worst method was developed for fuzzy and hierarchical conditions by Sadeghi et al. (2021). The number of questions in best-worst method is much less than in other methods like AHP, ANP and SWARA, the calculations are faster, and hybrid, and the results are more reliable in the Hierarchical Fuzzy Best-Worst Method (HF-BWM) (Sadeghi et al., 2021). The steps of this method are as follows (Sadeghi et al., 2021):

Step 1. Determining the best and worst criteria: This step could be determined using expert opinions.

Step 2. Comparison of the best criterion with other criteria and other criteria with the worst criterion: Experts used Table 2 to give points.

Table 2: The Consistency Index and Verbal Spectrum of the Fuzzy Best-Worst Method (Guo & Zhao, 2017)

Linguistic Terms	Equally Importance	Weakly Important	Fairly Important	Very Important	Absolutely Important
\tilde{a}_{BW}	(1,1,1)	$(\frac{2}{3}, 1, \frac{3}{2})$	$(\frac{3}{2}, 2, \frac{5}{2})$	$(\frac{5}{2}, 3, \frac{7}{2})$	$(\frac{7}{2}, 4, \frac{9}{2})$
	3.00	3.80	5.29	6.69	8.04

Step 3. Creating a model of HF-BWM: In this step, the weight of the factors can be calculated using the nonlinear programming model (Equation 1).

$$\text{mine}^L + \sum_j e_j^L$$

s.t.

$$|\tilde{W}_B - \tilde{a}_{Bj} \cdot \tilde{W}_j| \leq e^L, \forall_j$$

$$|\tilde{W}_j - \tilde{a}_{jW} \cdot \tilde{W}_W| \leq e^L, \forall_j$$

$$|\tilde{W}_B^j - \tilde{a}_{Bk}^j \cdot \tilde{W}_k^j| \leq e^L_j, \forall_j \& \forall_k$$

$$|\tilde{W}_k^j - \tilde{a}_{kW}^j \cdot \tilde{W}_W^j| \leq e^L_j, \forall_j \& \forall_k$$

$$G \tilde{W}_k^j = \tilde{W}_j \cdot \tilde{W}_k^j, \forall_k$$

$$\sum_j R(\tilde{W}_j) = 1, 0 \leq l_j^W \leq m_j^W \leq u_j^W, \forall_j$$

$$\sum_j R(W_k^j) = 1, 0 \leq l_k^{Wj} \leq m_k^{Wj} \leq u_k^{Wj}, \forall_j \& \forall_k \quad (1)$$

Step 4. Solving the model by one of the optimisation software: By solving this model, the weights of the criteria of each expert are obtained. After solving and calculating the weight of criteria, weights obtained from each expert are combined with the geometric mean method.

Step 5. Determining the consistency index (CI) by dividing the obtained result by CR to get the compatibility index value (Table 2).

Result

The Results of the Statistical Population

Table 3 shows the demographic data of the target population.

Table 3: Personal Profile

Sex	No	Graduate	No	Age	No	Experience	No	Position	No
Men	24	BC	8	31-35	4	6-10	7	Expert	9
		MC	10	36-40	14	11-15	13	Supervisor	7
Women	12	Ph.D	8	40>	8	16-20	6	Manager	10

The Reliability

the obtained result by CR to get the compatibility index value (Table 4). The obtained values are shown in Table 5.

According to step 5 of the best-worst method, divide

Table 4: The Consistency Index of the Questionnaire

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	
0.0637	0.0657	0.0616	0.0723	0.0741	0.0677	0.0655	0.0728	0.0649	0.0671	ξ^*
0.0277	0.0285	0.0267	0.0314	0.0322	0.0294	0.0285	0.0316	0.0282	0.0292	CI

As can be seen, the questionnaire has consistency. Therefore, its reliability is confirmed.

the main and secondary criteria, as the final weight of the criteria of poka-yoke indicators. The results are described in the table. In the Table 5 are included after the code column, the non-fuzzy weight column of each item, then the normal weight of each item and the ranking of the items.

Prioritising Indicators

By geometrically combining was obtained the weights of

Table 5: Results of Questionnaire Analysis

Code	Non-Fuzzy Weight	Normal Weight	Rank	Code	Non-Fuzzy Weight	Normal Weight	Rank in Segment	Rank
C1	0.3107	0.3127	1	C1.1	0.1983	0.1330	1	1
				C1.2	0.0750	0.0503	2	5
				C1.3	0.0376	0.0252	3	12
C2	0.1341	0.1349	2	C2.1	0.0151	0.0101	8	29
				C2.2	0.0910	0.0611	1	2
				C2.3	0.0831	0.0558	3	4
				C2.4	0.0745	0.0500	4	6
				C2.5	0.0741	0.0497	5	7
				C2.6	0.0442	0.0296	6	10
				C2.7	0.0326	0.0219	7	16
				C2.8	0.0844	0.0566	2	3
C3	0.1221	0.1228	3	C3.1	0.0121	0.0081	4	34
				C3.2	0.0300	0.0201	2	19
				C3.3	0.0552	0.0370	1	8
				C3.4	0.0247	0.0166	3	22
C4	0.0781	0.0786	4	C4.1	0.0477	0.0320	1	9
				C4.2	0.0101	0.0068	3	36
				C4.3	0.0200	0.0134	2	25
C5	0.0674	0.0678	7	C5.1	0.0136	0.0091	3	31
				C5.2	0.0167	0.0112	2	27
				C5.3	0.0066	0.0045	4	41
				C5.4	0.0303	0.0204	1	17
C6	0.0716	0.0721	5	C6.1	0.0429	0.0288	1	11
				C6.2	0.0086	0.0057	3	37
				C6.3	0.0202	0.0135	2	24
C7	0.0716	0.0720	6	C7.1	0.0156	0.0105	2	28
				C7.2	0.0133	0.0089	3	32
				C7.3	0.0069	0.0046	4	40

Code	Non-Fuzzy Weight	Normal Weight	Rank	Code	Non-Fuzzy Weight	Normal Weight	Rank in Segment	Rank
				C7.4	0.0355	0.0238	1	14
C8	0.0511	0.0514	9	C8.1	0.0102	0.0069	2	35
				C8.2	0.0048	0.0032	4	42
				C8.3	0.0081	0.0054	3	38
				C8.4	0.0280	0.0188	1	21
C9	0.0529	0.0532	8	C9.1	0.0292	0.0196	4	20
				C9.2	0.0303	0.0203	3	18
				C9.3	0.0328	0.0220	2	15
				C9.4	0.0356	0.0239	1	13
				C9.5	0.0241	0.0162	5	23
				C9.6	0.0138	0.0093	6	30
				C9.7	0.0076	0.0051	7	39
C10	0.0342	0.0344	10	C10.1	0.0187	0.0126	1	26
				C10.2	0.0033	0.0022	5	45
				C10.3	0.0133	0.0089	2	33
				C10.4	0.0022	0.0015	6	46
				C10.5	0.0044	0.0029	4	44
				C10.6	0.0044	0.0030	3	43

As can be seen in the Table 5, according to experts the main index of quality management (C1) is the most important index, technological capability, and innovation (C2), identification of human errors (C3), increasing the capability of personnel (C4) and identification of problems (C6) have second to fifth priority.

Among the main indicators, the error-proof solutions of quality management and its establishment were recognised as the most important dimension. Today, the root analysis approach is known in various organisations as a main preventive strategy in the implementation of any quality management system such as ISO 9001, EFQM, etc. This issue, which is considered an integral part of comprehensive quality management, is considered a key solution in information systems. The second indicator is important, innovation ability and technology that can greatly help in making information systems Mistake-Proof.

The use of pre-designed cracker lists, providing appropriate defaults for information items, as well as improved data model structures can strengthen technological and innovative approaches in information systems. Since improving the ability of innovation and technology in an organisation has a lot of fusion with the proper cultivation of talents and abilities, it is necessary to consider training and development of skills in order to develop this side of human resources Mistake-Proof. The third dimension, which is the most important among the various dimensions

of error-proofing, is the identification of human errors. In this dimension, the use of a warning system and controller is the most important sub-criteria. This dimension has been considered an important dimension in error-proofing in similar research in the field of industry.

Regarding the following indicators, proper planning of quality management programs (C1.1) is the most important factor, and then building information modeling (C2.2), proper implementation of the productivity cycle (C2.8), development of various types of databases and business intelligence (C2.3) Skilled employees, advanced facilities and equipment (C1.2) are in the second to fifth priority respectively as Mistake-Proof solutions of supply chain control tower systems. These indicators are the things that should be considered by the managers in order to develop the Mistake-Proof of the construction supply chain control tower systems. By focusing on these items, managers can gradually expand this system to other items and even identify and add other items according to the type of their project.

Future Research and Limitations

Since the main approach of this research is to introduce and prioritise different dimensions of poka-yoke in control tower systems in the SAAL supply chain in the construction industry, Future researchers should consider the following when applying the results of this research.

At the time of designing the principles of comprehensive quality management, consider the human, systemic and hardware aspects of the systems. Security problems in the design of a control tower system should be investigated for the possibility of coordination with other systems. In future research, the discussion of risk analysis as a key part of poka-yoke in control tower systems can be considered as well as the development of security and information quality approaches.

Conclusion

In today's era, which has increasing complexity in various technological fields, people and businesses around the world have paid attention to the approach of using easy ways and methods in performing their tasks or implementing their processes. In the meantime, information systems such as the supply chain control tower have also faced many advances to provide a correct method for finding information or processing a job so that users are given the right access and the right task. Although the developers of information systems have progressed to some extent and have used techniques that do not cause any problems in their development or implementation, there are always many problems in practice.

These problems will be very difficult, especially in industries such as construction which is very traditional and has many complexities. In addition, in a country like Iran, which is a crisis-ridden country, where the construction industry is in the hands of non-specialists, it is very difficult to implement such systems, so it has a high potential for errors. Although in other research, various solutions and methodologies have been considered for the development of control tower systems, in this research, the issue has been examined from the point of view of error-proofing. Therefore, based on studies in the field of information technology, it was tried to identify and prioritise all solutions for making information systems fail-proof for this purpose.

In this research, due to the lack of specialised information about the supply chain control tower, after a comprehensive review of the research literature, the effective factors on the poka-yoke of information systems were identified. 46 poka-yoke solutions were identified for information systems such as control towers. Then, they were divided into 10 categories of main criteria with the opinion of experts and experts using nominal group techniques and final approval. The prioritisation of these solutions was done based on the opinions of supply chain experts and with the help of a questionnaire using the best-worst method.

The results showed that factors such as proper planning of quality management programs, building information modeling, proper implementation of the productivity cycle, development of various types of databases and business intelligence, skilled employees, and advanced facilities and equipment are the most important factors. Another goal of this research is to create an implementation strategy that increases the satisfaction of stakeholders and acceptance of stakeholders during the implementation of control tower systems in the construction supply chain. The results said, if quality systems are improved, new technologies are used in an optimal way, and with the aid of existing tools, human errors are identified and categorised, and according to them, efforts are made to increase the skills of employees, then poka-yoke will be strengthened.

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