

# Tower Control Approach for SAAL Supply Chain Strategy in the Construction Industry of Iran

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## ABSTRACT

In the Chaos/Anarchy business environment of the construction industry of Iran, the Sustainable Antifragile Agile Lean (SAAL) supply chain strategy was proposed as antifragile and value-creating approach. In this strategy, just-in-time data management and analysis are very important to make decisions. The control tower as a controlling unit based on data is the core of this supply chain. The purpose of this article is to investigate the implementation of the control tower in the supply chain of the construction industry. For this purpose, two goals should be followed. The first step is to determine the main indicators to focus on for the initial implementation of the control tower. The second step is to measure the considered indicators using the available data from before the implementation, and after the implementation to compare the performance. To achieve the first goal and to identify the categories of information these categories were divided into three main categories: upstream, midstream and downstream. According to experts' opinion was considered the middle part of the supply chain, which is carried out on the site by an executive team. At this stage, among the available indicators, the most important indicators were considered using the best-worst method according to previous projects' data to compare the data. The results of the implementation of a control tower approach showed that it provides the possibility of managing manufacturing operations. This system can guide the managers of the organisation to identify the best strategies and improve risk management in response to the needs, requirements, guidelines, and changing opinions of the stakeholders and external global conditions.

**Keywords:** Control Tower, Supply Chain, Sustainable, Antifragile, Agile, Lean

## Introduction

The main goal in construction projects is to reduce cost and risk, and increase project speed with continuous quality improvement. This should be performed throughout the supply chain process. As a result, managers should choose operational methods in their management structures so that all available resources are planned in the best possible way in terms of effectiveness and efficiency, without compromising the safety of employees and customers and even the project. Therefore, it can be said that the supply chain is the most complex process in terms of human resources, economic resources, securing the interests of

stakeholders, construction equipment, ICT systems and risks and the construction process. For this reason, there is a need to closely monitor all the tasks performed by the employees and professionals involved in the entire construction process (Hill et al., 2021).

Today, the construction industry is described and analysed as a production process. The construction process absorbs a large number of facilities (about 70%). The increase in costs in the coming years, due to the ever-increasing inflation and other economic problems of Iran, and on the other hand, the arrival of new materials and the development of technologies used in construction

projects, will cause the costs to rise every day. Since any process that allocates a resource to itself is not known, it can cause a waste of time and money, now the question is raised, how can it be managed and improved efficiency in this situation? How can this approach be achieved? “If we can measure something, we can understand it. If we can understand it, we can control it, now we can improve it (Nurse et al., 2018).” For this reason, the management team must be able to identify, track and manage with absolute transparency all the stages of this chain that make up the complex path of each supply, production and construction of each part.

With the aid of this information, managers can make all the necessary changes in the workflow, and as a result, the system becomes more effective. In other words, providing better information leads to better service to employees, providing better service to employees, leads to increased efficiency, reduces business costs, providing better products (goods/services) to customers (Midkiff, 2021; Sadeghi, 2022). This issue is very effective and vital, especially in complex and chaotic/anarchy situations.

According to the studies, the control tower has not been implemented in the construction industry. This research deals with this issue according to this gap and Iran’s conditions. The goal of this project is to create Control Tower Approach (CTA) to obtain and provide better information. For this purpose, it has been tried to create and test a CTA in one of the parts of the supply chain. The main question that arises is whether is it possible to create such a system in the supply chain of the construction industry? If possible, what indicators should be considered? Does this system work? To answer these questions, according to the opinion of experts, among the Sustainable Antifragile Agile Lean (SAAL) strategy indicators, the most important indicators should be selected in the first step. For this issue, according to the type of activities, tools for those departments should be considered. Therefore, in this article, theoretical foundations are defined in the first part. In the second part of the methodology, in the third part, the measurement results are given.

## RESEARCH LITERATURE

### Construction Supply Chain

The supply chain is the heart of any operational project. This issue is especially important in construction due to the complex conditions and the existence of multiple stakeholders with diverse demands. Because in construction projects there is a lot of uncertainty due to

its unpredictable environment and the variety of interests (Demir, 2015). On the other hand, the construction supply chain has many vast and abundant dimensions than other industries. This supply chain consists of phases of design, planning, sourcing, transportation, warehousing, production, executive operations, human resources, delivery and sales. In other words, a typical supply chain for a construction project includes engineers, architects, prime contractors, material suppliers and specialty subcontractors who come together to work on a single project. Each of these departments is divided into sub-categories and each has various officials and stakeholder (Benton & McHenry, 2010; Sadeghi et al., 2022).

Because the construction industry provides a variety of physical facilities (e.g., dams, roads, bridges, residential and commercial buildings, factories, recreational facilities, etc.), it has a large impact on society, the environment and the economy. Therefore, in the supply chain management of construction projects, in addition to the project management approach, lean, agile and sustainable approaches were also used in various forms. These new management approaches can be the best way to deal with the complexity of construction projects and the balance between the three sustainability elements that play an important role in the construction industry and the environment compared to other industries, in order to achieve maximum performance in the future (Ghazali, 2019; Subani et al., 2020).

With proper synergy between construction project management techniques and supply chain management, favourable conditions can be obtained to reduce delivery time, increase quality and minimise waste, rapid response to changes in sustainable product production to achieve the goal of benefits realisation of domestic and foreign stakeholders, the continuation of activities under unsustainable conditions, and economic and social development for sustainable development (Ma & Kremer, 2016). This is the logical reason to use these new approaches alongside the traditional approach (Dallasega et al., 2018).

### SAAL Supply Chain

The fragmented supply chain and short-term thinking of construction companies, the short-term nature of construction projects, and the lack of long-term investment, limit the use of capabilities, which is also an obstacle to innovation. On the other hand, tight competition and economic and social crises, that pushes Iran’s society towards an anarchy/chaotic environment

(critical situation), also make the conditions of project management more complicated and difficult. 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 R Greene (2010) said at a time when Project/Organisation are in a critical situation on the one hand, and on the other hand, it is in a position of weakness and defence, 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, 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 (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 (Sadeghi et al., 2022; Tembo & NicholasTaleb, 2012).

In this regard, W. Chan Kim (2005) in the book *Blue Ocean Strategy* introduced a new strategy as an approach to move from the red ocean to the blue ocean, with the help of innovation in value. The purpose of this strategy is to create value in a chaotic environment (Kim & Mauborgne, 2017). In another example, Nassim Nicholas Taleb (2015), talks about how to benefit from chaos in the book 'Antifragile'. He states that shocks make the system more resistant and make it become resilient, but when a system reaches this level of resilience, it becomes difficult to defeat (Tembo & NicholasTaleb, 2012).

The Sustainable Antifragile Agile Lean (SAAL) strategy is a supply chain strategy, an antifragile value-creating efficient paradigm in the construction industry to face such chaotic conditions (Sadeghi et al., 2022). In 2019, Tahseen Group showed that in a construction project, by applying the SAAL supply chain strategy, it can increase its efficiency in terms of cost reduction, risk management and customer acquisition to control all processes. SAAL's 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 turning numbers into available information for construction industry managers to influence process management (Sadeghi et al., 2022). SAAL strategy, in line with the words of Nassim Taleb and W. Chan Kim, by exploiting agile, lean, flexible, resilient, sustainable approaches and 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. In order to create such an antifragile and value-creating system, the following nine principles are suggested (Zarghami & Dumrak, 2021): (1) Further strengthening the disaster risk management system, especially at the micro level, (2) Timely and proportionate response/reaction, (3) Resilient infrastructure including social, economic and environmental, (4) Flexible financial system with fair access to savings, financial credit and insurance, (5) Social support, especially for people at the bottom, (6) Management of sustainable natural resources, (7) decentralised integration, (8) Reducing costs and waste, (9) Revision, continuous improvement of actions and re-creation. As a result, according to these cases, the phases of the supply chain in the SAAL strategy were expanded with regard to the construction industry in Iran for monitoring and control (Table 1).

**Table 1: SAAL Construction Supply Chain Phases (Sadeghi et al., 2022; Sadeghi et al., 2022).**

Phase	Duties
Scheduling	Companies must plan and manage all the resources needed to meet customer demand for their products or services. They must also design, and plan their supply chain and then determine which metrics they will use to ensure that the supply chain is efficient and effective.
Planning	The plan is the most important stage of the supply chain because the conclusions made in the design stage will have a significant impact on the supply chain life cycle environment. This plan should be given the main attention to identify the possible effects on the project about its possible effects in all dimensions.
Sourcing	What is meant by this is the suppliers that companies choose to provide the goods and services needed to produce their products. After signing the contract, the supply chain managers use various processes to monitor and manage the relationship between the two parties. The main processes of this department include ordering, receiving, inventory management, human resource management and approval of supplier payments.

Phase	Duties
Logistic	This includes coordinating customer orders, determining delivery times, sending cargo, invoicing customers and receiving payments. This sector relies on vehicles to deliver products to customers. Many organisations outsource many parts of the delivery process to specialist organisations, especially when the product requires special checks. The process of planning, execution and control for the efficient and effective transportation and storage of goods is defined among these services, and on the other hand, it provides related information from the point of origin to the point of destination to meet the needs of the customer.
Production/ Manufacturing	Supply chain managers always consider the activities necessary to accept raw materials, product production, quality testing, packaging, transportation and delivery schedule among the main principles. Most companies evaluate the quality, production rate and productivity of workers to ensure that the company produces products according to the accepted standards of the market.

Phase	Duties
Operation and maintenance	Operation and maintenance programs include training, maintenance process until delivery, clearance, work application and control to preserve materials and resources, even human resources and all stakeholders in the project according to the needs of sustainable development, including these services.
Support	The supplier needs a responsive and flexible network for returning defective, surplus, or unwanted products. If the product is defective, the product is not what the customer wanted, or the excess of what was ordered was delivered, it must be returned to the warehouse for inspection. In addition to these cases, all reverse logistics operations are also defined among these services.
Final evaluation	For greater efficiency, the supply chain needs to monitor information throughout the chain and ensure compliance with all regulations. The processes of this stage include finance, human resources, information technology, facilities, portfolio management, product design, sales, and quality assurance.

Based on these principles and the supply chain phases of the SAAL strategy, the key performance indicators of this supply chain were determined. With the help of surveys and experts' opinions, these indicators (criteria) were

categorised based on sustainable development functions (Operational-Social, economic and environmental performances) as described in Table 2.

**Table 2: SAAL supply Chain Key Performance Indicators (Criteria) of the Construction Industry (Sadeghi et al., 2022).**

Indicators	#	Sub-Indicators	#	Indicators	#	Sub-Indicators	#			
Operational-Social performance	C1	Prosperity, health, safety and security	C1.1	Economic performance	C2	Cost	C2.1			
		Inventory level	C1.2			Productivity, efficiency and cash conversion cycle	C2.2			
		Customer Orientation	C1.3			Environmental costs	C2.3			
		Quality	C1.4			Environmental revenues	C2.4			
	Resilience and flexibility	C1.5	Time	C1.6	Environmental performance	C3	Pollutants	C3.1		
							Local influence	C1.7	Green image	C3.2
							Decentralised integration and modularise	C1.8	Business waste	C3.3

As it is known, one of the main goals of SAAL strategy is to benefits realisation management of all stakeholders (Sadeghi et al., 2022). In order to achieve this purpose, it can be very useful to have sufficient and real-time information in each of the departments according to the functions. One of the effective tools for this purpose in the SAAL strategy is the CTA.

This approach makes it possible to have a unified view of all nodes of the supply chain, display the current situation and even examine the future situation under different scenarios. In this way, managers are able to monitor the milestones of each department at any moment and according to the conditions, determine and implement strategies or special approaches according to the concept

of Dynamic Flexible Innovative/Disciplined Approaches (IDEA). The concept of IDEA<sup>1</sup> states that a construction project faces various environmental characteristics from predictable to uncertain during its project life cycle. Therefore, construction project supply chain management should become more strategic like a battlefield.

### Control Tower Approach (CTA)

With the booming development of global wireless communications and the proliferation of connected mobile devices, Internet users are no longer confined to traditional wired environments. The integration of wireless communication and mobile Internet services is considered one of the most promising investments. In an age where the speed of technology has become much faster than in the past, the combination of various technologies such as IT, ICT, IoT, blockchain, artificial intelligence, etc., is creating serious, systematic and profound changes in human life (Maskuriy et al., 2019).

The fourth industrial revolution aids connect technology and people, with this breakthrough in technology, humanity can find new ways to express its capabilities by removing the boundary between physical, digital and biological beings. These modern techniques not only support every component in the industry. It is also sustainable (Dalenogare et al., 2018; Mastos et al., 2020). Because it can reduce waste on the one hand and use renewable energy and increase energy efficiency on the other hand (Mrugalska & Wyrwicka, 2017). Now, many industries have realised that by connecting their employees to equipment and equipment to each other at any time, the efficiency of activity increases and costs decrease, and a resilient and

sustainable production system is created (Sharabati et al., 2022). One of these tools that provide the possibility of tracking and controlling activities is the control tower.

The control tower 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 control tower 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 control tower 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 control tower 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). Therefore, it can be stated that the construction industry, due to the complexity, extent and diversity of its supply chain activities, implementing the control tower approach, an approach with which monitoring, collection, analysis and management of data are able to highlight important issues and better allocate resources in terms of efficiency and sustainability. Also, it can effectively workflows of supply chains lead and manage. For this purpose, it is vital to identify information categories. For this reason, it is necessary to first divide the whole process of the construction chain into three main categories: upstream, midstream and downstream (Fig 1).

<sup>1</sup> This approach is fully described in another article.

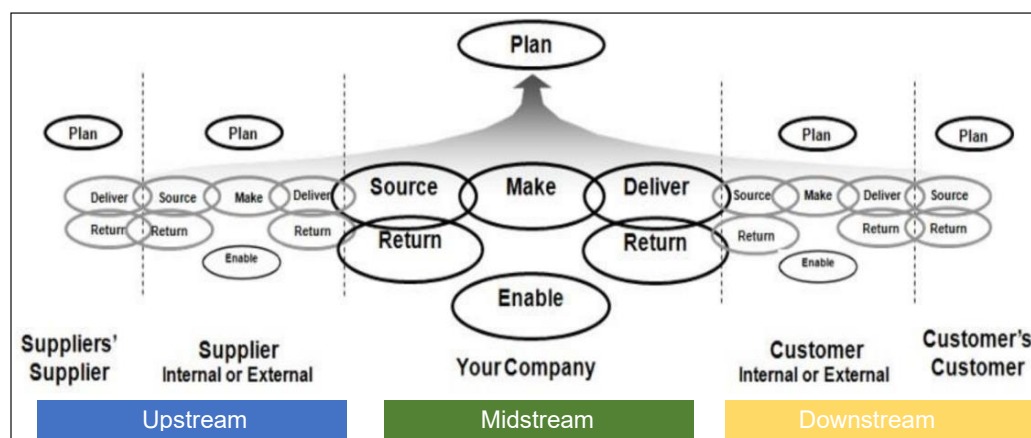


Fig. 1: Supply Chain Segmentation with the Help of the SCOR Model (Kusrini et al., 2019)

The upstream part of the supply chain includes the organisation's suppliers and the processes of managing relationships with them. Due to the focus of the business unit in the supply chain, upstream activities include suppliers of raw materials. Upstream activities can include a supplier that supplies these materials or resources to fulfil orders. The upstream category contains information about project resources to cover supply, which includes managers and staff and their needs in terms of equipment and other issues. After upstream, there are midstream phases (warehousing, human resources and executive operations). Midstream activities include activities that occur at the project or organisation site. The midstream category contains information about project resources, and activities taking place in the project, in order to cover the implementation of operations, which includes managers and employees and their needs in terms of actions and other issues. The downstream sector includes the organisations and processes of distribution and delivery of products to final customers. The downstream category contains information that identifies customers and their needs in terms of quality. The activities of each of these departments are divided into several phases to manage and improve productivity (Kusrini et al., 2019; Midkiff, 2021).

These phases and sections are given in Fig. 1. In this project, according to the opinion of experts, attention was first paid to the midstream to start the control tower approach. Since the midstream of the supply chain is considered in this project, until the end of 2021, this system was able to track the entire supply chain flows in six projects from the beginning to the end. It was also able to identify the people who were involved in each stage and the places where different activities were carried out.

These steps were implemented with the help of BIM, GIS, RFID integration (Darko et al., 2020; Zhu & Wu, 2022), applications in mobile phones, block chain, data warehouse, a business intelligence system and basic artificial intelligence (Ma et al., 2022; Marzouk & Hanafy, 2022; Rodrigues et al., 2022), with the aid of a supply chain expert as the person in charge of supply chain process management, who regularly shared the project process board with the experts of the supply chain blocks, the relevant key performance indicators, from the beginning of design, transportation and warehousing to implementation. Since the architectural model of this control tower is out of the scope of this article, it is presented in another article.

The steps described above are fundamental to the proper planning and scheduling of the production process, because if not included in the proper planning process, daily work may cause bottlenecks in the process. What is discussed in this article is the evidence that shows that today the construction process can be considered a production process. In the following, the results of using the control tower approach are stated.

## METHODOLOGY

The main issues of any supply chain process are: the needs and requirements of the objectives, the problems to be solved, the effort to obtain the data and the value of the data. 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 a proper analysis of this data and search for questions that support these 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.

For this reason, in order to satisfy this issue, this project has progressed in five phases. Considering the focus on the midstream part, in the first phase, with the help of performance indicators presented in Table 2, a questionnaire is designed to determine the most important indicators. Five important indicators for the initial focus in order to create a control tower are determined in the middle section. Then the desired functions for those indicators are determined according to the opinion of experts. In the second phase, the weight of the desired functions for the selected indicators is determined with the help of a questionnaire. In the third phase, performance data from several previous projects are included according to the specified indicators. Finally, in the fourth phase, by entering the functional data of the running projects, information is compared.

### Selection of Statistical Population

The statistical population of this project is the experts of Tahseen Company and the employers of the mentioned projects. Two questionnaires have been used in this project. The statistical population of both questionnaires is fixed.

## 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 method of analysis of all three questionnaires to determine the weight of the criteria is HF-BWM. 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 by using expert opinions.

Step 2. Comparison of the best criterion with other criteria and other criteria with the worst criterion: Experts used Table 3 to give points.

**Table 3: 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
$\tilde{\alpha}_{BW}$	(1,1,1)	$(\frac{2}{3}, 1, \frac{3}{2})$	$(\frac{3}{2}, 2, \frac{5}{2})$	$(\frac{5}{2}, 3, \frac{7}{2})$	$(\frac{7}{2}, 4, \frac{9}{2})$
CI	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 by using the nonlinear programming model (Equation 1).

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

s.t.

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

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

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

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

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

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

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

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

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.

## RESULT

### The Results of the Statistical Population

Table 4 shows the demographic data of the target population.

**Table 4: Personal Profile**

Sex	No	Graduate	No	Age	No	Experience	No	Position	No
Men	11	BC	5	31-35	6	6-10	6	Supervisor	8
		MC	7	36-40	5	11-15	4	Chief	4
Women	3	Ph.D	2	40>	3	16-20	4	Supervisor	2

## The Results of Analysis the First Phase

### The Reliability of the Questionnaire

According to step 5 of the best-worst method, divide the obtained  $e^L$  result by CR to get the compatibility index value (Table 3). The obtained values are shown in Table 5.

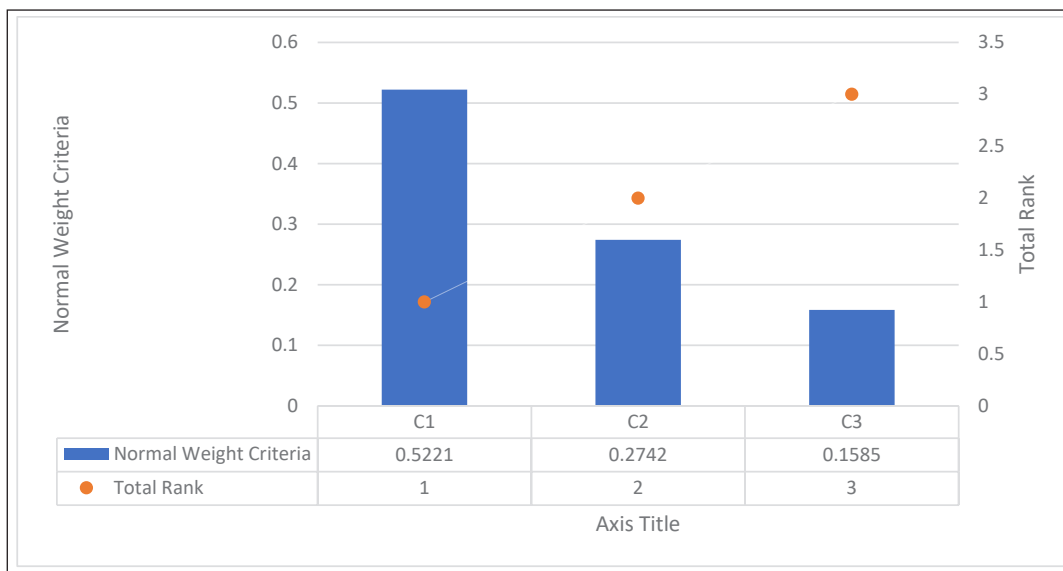
**Table 5: The Consistency Index of the Questionnaire**

Main Indicator		C1		C2		C3	
$\xi^*$	CI	$\xi_{1}^*$	CI	$\xi_{2}^*$	CI	$\xi_{3}^*$	CI
0.067	0.029	0.065	0.028	0.072	0.031	0.064	0.028

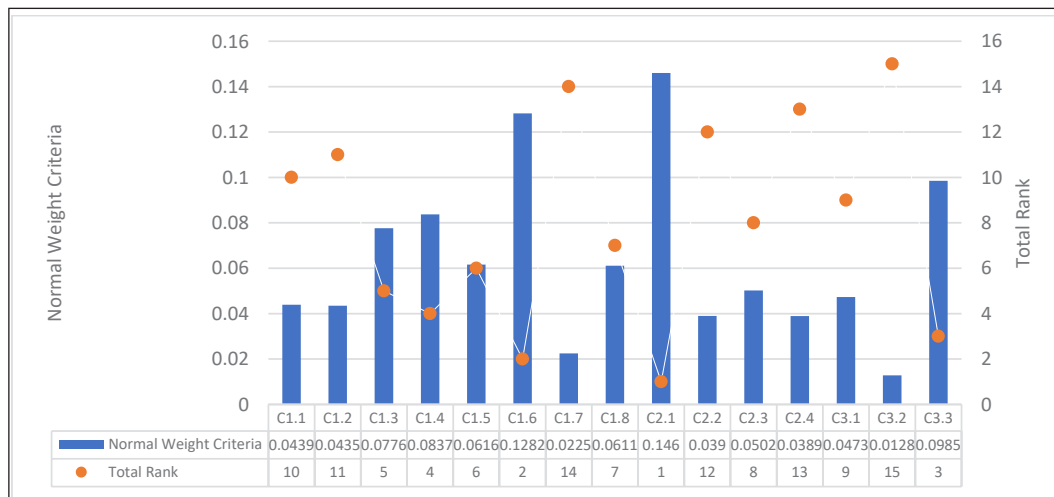
As can be seen, the questionnaire has consistency. Therefore, its reliability is confirmed.

### Calculating the Final Weight of SAAL Supply Chain Performance Criteria

As explained in Section 3, with the help of a designed questionnaire, the top five indicators of the SAAL supply chain strategy were determined. After analysing each of the questionnaires, the final weight of the indicators was obtained with the geometric sum of the obtained weights. Finally, the weights were normalised for the final ranking, thus the normal weight of indicators and sub-indices and their ranking are presented in Fig. 2 and 3.



**Fig. 2: Importance of the Weight of Criteria of SAAL Supply Chain**



**Fig. 3: Importance of the Weight of Sub-Criteria of SAAL Supply Chain**

As can be seen in Fig. 3, according to the ranking done in the overall ranking column, cost is the first rank, time is the second rank, business waste is the third rank, quality is the fourth rank, and customer orientation is the fifth rank. This shows that operational and economic issues are of great importance in the SAAL supply chain for the continuation of the activity. This shows the direct connection between economic and operational issues.

According to the results of the analysis, in order to carry out the implementation stage, functions should be considered for the most important selected criteria. In line with the contents stated in Section 3, the company's experts considered functions for these criteria. The functions are given in the "Selective Index Function" column of the Table 6.

**Table 6: Sub-Criteria's Rank & Function**

Sub-Criteria	Rank	Function
Customer Orientation	5	%Tasks meet the expectations of applicants
Quality	4	QPI <sup>1</sup>
Cost	1	CPI <sup>2</sup>
Time	2	SPI <sup>3</sup>
		Overtime%
Waste	3	%Tasks Stopped/killed
		%Rework

The main criteria in the supply chain are "Cost and Time". Time itself is a direct factor in cost. The main goal of management is to allocate appropriate time to each service on any given day in order to reduce the cost of the supply chain process.

The SPI function is equal to the relation 2 and the CPI function is equal to the relation 3 which is calculated through the software. The agreed function for QPI is equal to the relation 4 finally, the final efficiency GPI index is determined. The agreement function for GPI<sup>2</sup> is equal to the relation 5.

$$SPI = EV^3 / PV^4 \quad (2)$$

<sup>2</sup> Gold Performance Index

<sup>3</sup> Earned Value

<sup>4</sup> Planned Value

$$CPI = EV/AC^5 \quad (3)$$

$$QPI = (W_{CPI} * CPI) + (W_{SPI} * SPI) + (W_{\%Rework} * \%Rework) + (W_{\%Tasks\ meet} * \%Tasks\ meet) \quad (4)$$

$$GPI = (W_{CPI} * CPI) + (W_{SPI} * SPI) + (W_{QPI} * QPI) \quad (5)$$

The value of W is also calculated with the help of a questionnaire through the FH-BWM method.

## The Results of Analysis the Second Phase

In order to determine the weights of QPI and GPI functions, a questionnaire was again designed using the Best-Worst method. The second questionnaire consists of two parts. The first part is related to the determination of QPI weights and the second part is related to GPI weights. The weight of the functions is given in the Table 7.

**Table 7: Weight of Functions**

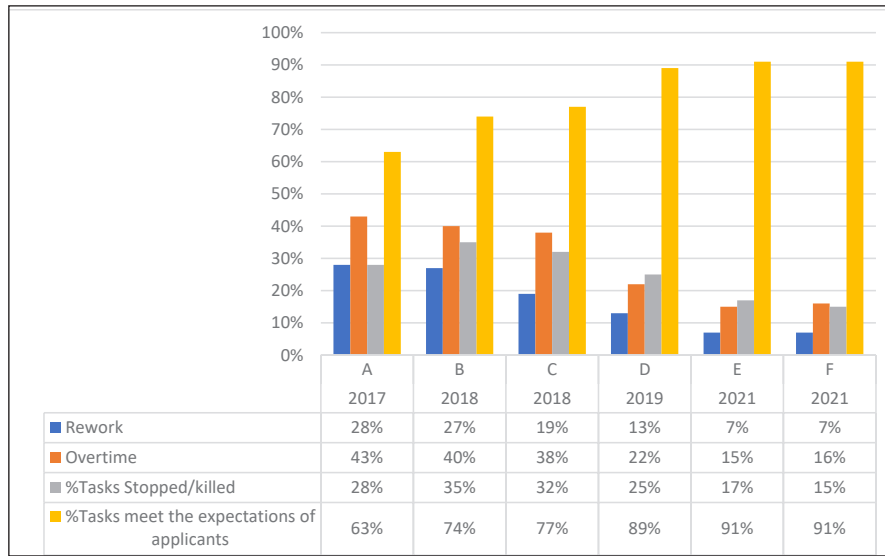
Part1	Function	SPI	CPI	Rework	%Tasks meet ...
	Weight		0.268	0.472	0.179
Part2	Function	SPI	CPI	QPI	
	Weight		0.225	0.65	0.125

## The Results of Analysis the Third and Forth Phase

In order to create this control tower, first all the phases of this supply chain and their set of operations were extracted in the desired middle section. Then, in order to launch and review the chain of operations, the most important actions that are of great importance in terms of cost, time and quality were selected according to the experts. Now, according to them, data related to previous projects were extracted for comparison. The data obtained in Fig. 4 includes the years 2017, Project A, 2018, Project B, 2018 and Project C. In Project D in 2019, the control tower was created and data was entered. In 2020–2021 data from projects E and F were reviewed by the control

<sup>5</sup> Actual Cost

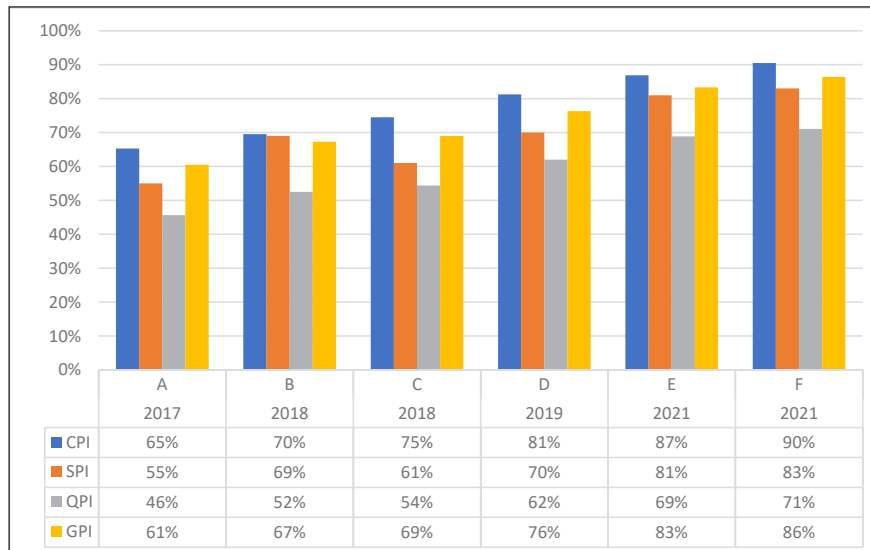
tower.



**Fig. 3: Evidence from the Supply Chain Block**

The %Tasks Stopped/killed items decreased from 28% in Project A in 2017 to 22% in Project F in 2021. Overtime, to compensate for delays, was reduced from 32% in Project A in 2017 to 18% in Project F in 2021. Rework decreased from 23% in Project A in 2017 to 11% in Project F in 2021. In 2019, CTA started with Project D.

In order to check the efficiency of the project, indicators were selected by experts, which are given in the table. Fig. 5 describes the impact of the main performance indicators.



**Fig. 5: Efficiency Criteria of the Supply Chain Block**

Item SPI increased from 55% in Project A in 2017 to 83% in Project F in 2021. Item CPI increased from 65% in Project A in 2017 to 90% in Project F in 2021. This also applies to other indicators.

The possibility of real-time control of activities, real-time presentation and display of the current situation and prediction of the future situation provides the possibility of improving decision-making in order to take necessary

actions and compensate for mistakes. Despite the limitations of Iran's Internet, the use of an integrated and decentralised system made it less difficult to share and make decisions. In addition to these cases, some cases were observed in the implementation of this system that can have a significant impact on the project process. For example, organisational culture plays an effective role in advancing project goals. With continued implementation and development and the use of various factors, the results will improve significantly.

## DISCUSSION

### Implications for Theory

This project tried to provide a new way to optimise control of supply chain operations in the construction industry. According to the conducted research, the optimal control of the processes provides the possibility of improving the processes. In this system, with continuous control of the processes, it is possible to improve and even prevent harmful events before they occur. The preliminary results of this research in Section 4 refer to this issue. Preliminary research showed that there are many indicators that can be considered in order to control different parts of the supply chain. Unfortunately, only a few indicators are examined in Iran's construction industry. In this project, the focus was on those indicators.

### Implications for Practice

The report of this project states that it is not possible to reduce or control inefficiency even in an efficient system. This could be due to translation efficiency/inefficiency problems in operation lists. The concept of "Capacity" is described as lists of operational operations available by hours or days of operation time per week and month. Therefore, to optimise the supply chain capability, the list of activities should be determined based on the historical timing of the activity. To achieve this goal, there is a need for a coordination group that, as the control tower, can plan activities related to the needs of the stakeholders and the facilities of the organisation. This group should be multidisciplinary and led by a supply chain manager because he has the ability to see the big picture of the problems.

## Limitations of the Study and Future Research Directions

Iran's construction industry is a traditional industry. Most of the people who work in this industry do not have a university education in this field. Academic science in the field of construction management also does not pay attention to new developments. As a result, the indicators that are considered for project control are very limited. In addition, the supply chain is not paid attention to in Iran's construction industry. As a result, there are very few specialists in this field. In the next research, more indicators will be considered. In addition, other parts of the supply chain will be added to it over time.

## CONCLUSION

There are many processes in preparation, stakeholder satisfaction and sales that are not yet clear and cannot be evaluated by standard methods. However, by applying CTA, these processes can also be made accessible and transparent, so that the quality of services provided can be continuously improved and waste can be reduced. The implementation of CTA enables the management of supply chain processes, which can guide project managers to identify the best strategies to optimise resource consumption and improve stakeholder risk management in response to the guidelines and requirements of global and national standards.

In this project, in order to implement CTA, the supply chain was first divided into three parts upstream, midstream and downstream. For the sake of convenience and according to the available facilities, it was decided to implement the control tower in the middle section first. For this purpose, this section was investigated. According to the opinion of experts, the important tools and indicators in this department and the desired functions were determined. This action caused its effect to be investigated in a limited sector so that it can be developed along the supply chain little by little with planning based on needs assessment and facilities.

CTA's basic business intelligence and artificial intelligence capabilities provided the ability to explore different scenarios. This helped to optimise many decisions. The existence of a decentralised system also made the main

data available in case of communication problems and there was no disruption in planning and decision-making. The system was improved from 2019 to 2021. In the next phase, all the middle parts should be covered and then the upper and lower parts of the supply chain are covered and the results are reported.

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