QUALITY MANAGEMENT JOURNAL
2023, VOL. 30, NO. 4, 259–278
https://doi.org/10.1080/10686967.2023.2245087

ASQ
Excellence Through Quality

REVIEW ARTICLE

Check for updates

Investigating the critical success factors for integrating Lean Six Sigma and Industry 4.0

Nevien F. Khourshed

Department of Marketing and International Business at the College of Management and Technology, Arab Academy for Science, Technology, and Maritime Transport (AASTMT), Alexandria, Egypt

ABSTRACT

Despite the wealth of material available on Lean Six Sigma (LSS) and Industry 4.0 (I4.0), integration of LSS with I4.0 is rarely discussed. This study seeks to fill this gap by studying the critical success factors (CSF) of integrating LSS with I4.0 to enhance organizational effectiveness and efficiency. The methods of quantitative research were used to carry out this investigation. In total, 733 questionnaires were collected from different departments: supply, production, and IT. The questionnaire was used to gather data regarding employees' perceptions of the current state of LSS and I4.0 and the possibility of integrating LSS and I4.0 within their organizations. To integrate LSS with I4.0, it could be claimed that the CSFs of LSS that could be considered important for I4.0 implementation are utilization of the necessary procedures, techniques, knowledge, abilities, and experience to accomplish the project's goals, employees committed to the organization, the organization gives rewards and appreciation to employees for meeting a pre-determined goal, explaining activities and releasing the results in a transparent manner, monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets.

ARTICLE HISTORY
Received 10 January 2023
Accepted 22 May 2023

KEYWORDS
critical success factors; Egypt; Industry 4.0; Lean Six Sigma; manufacturing industry

Introduction

The most popular corporate approaches for attaining Continuous Improvement (CI) in the industrial and service sectors recently have been Lean and Six Sigma. Any organization's main goal should be CI to enhance performance, attain quality, and achieve operational excellence (Thomas, Barton, and Okafor 2008; Assarlind, Gremyr, and Bäckman 2013; Albliwi, Antony, and Lim 2015). Recently, other authors have realized the benefits of combining the two ideas "Lean Six Sigma (LSS)" (Laureani and Antony 2012; Assarlind and Aaboen 2014). A full explanation of the idea may be found in the remark provided by Laureani and Antony (2012) that "Lean Six Sigma leverages tools from both tool boxes to extract the most from the two methodologies, raising speed while also enhancing accuracy". Assarlind and Aaboen (2014) contend that while Six Sigma quality promotes Lean speed, the reverse is also true.

As well, Industry 4.0 (I4.0) technologies have the potential to support a number of performance enhancements, including cost reduction, improved product quality, better responsiveness, superior flexibility, collaboration with environmental sustainability and worker safety, shortened lead times and costs, and small batch customization (Lu 2017; Varela et al. 2019; Machado, Winroth, and da Silva 2020; Acioli, Scavarda, and Reis 2021; Chiarini, Belvedere, and Grando 2020; Piyathanavong et al. 2022). Hence, as stated by Bhat, Bhat, and Gijo (2021), the employment of LSS in the early phases of I4.0 could improve organizational effectiveness and efficiency by adopting data analysis through simulation.

However, numerous organizations did not profit from the deployment of LSS for I4.0 because of flaws in the literature. Therefore, there is an opportunity to research LSS integration with Industry 4.0, particularly in developing countries like Egypt.

The lines above imply that there is still few research that address how I4.0 and LSS might be combined. Accordingly, two research questions are developed, as follows:

1. How I4.0 and LSS might be combined to improve organizational effectiveness and efficiency within manufacturing industry in Egypt?

CONTACT Nevien F. Khourshed nevienfarouk@gmail.com, nevienkhourshed@aast.edu Department of Marketing and International Business at the College of Management and Technology, Arab Academy for Science, Technology, and Maritime Transport (AASTMT), Alexandria, Egypt.

2. What are the CSF's that affects I4.0 implementation and what are the LSS CSF's that can result in I4.0 implementation?

The following sections include the literature review, the research methodology, the findings, the discussion, and the conclusions.

Literature review

Lean and Six Sigma

Lean and Six Sigma have recently been the most widely used corporate methods for achieving continuous improvement (CI) in the industrial and service sectors. To improve performance, achieve quality, and achieve operational excellence, CI should be any organization's primary objective (Thomas, Barton, and Okafor 2008; Assarlind, Gremyr, and Bäckman 2013; Albliwi, Antony, and Lim 2015). Lean and Six Sigma are therefore more effective when used in conjunction than when used separately (Albliwi et al. 2014), and this effect may be observed in both the industrial and service sectors (Antony, Snee, and Hoerl 2017).

According to Vinodh and Joy (2012), lean manufacturing processes are connected to and help improve organizational performance. Understanding the motivations behind lean implementation in businesses, key obstacles, limitations, and rewards are just a few examples. Not many businesses, nevertheless, have genuinely benefited from lean (Anthony et al. 2019). Few developing economies have successfully carried out these programs (Chakraborty, Mutingi, and Vashishth 2019). Later, Kovács, Ko, and Demeter (2020) investigated how measuring the lean practices–performance relationship could add value to businesses, their results show that different performance areas may be affected differently and suggest that the measured relationship may depend on the reliability of the self-assessment.

Contrarily, Six Sigma is a business technique that aims to find and eliminate the core causes of mistakes, defects, or failures in business processes. It focuses on customer-important outputs (Snee 2010; Antony 2008). According to Näslund (2013), Shah, Chandrasekaran, and Linderman (2008), Manville et al. (2012), and Drohomeretski et al. (2014), Six Sigma seeks to improve customer satisfaction while lowering costs and measuring and reducing faults to 3.4 parts per million opportunities within a company (Chen and Lyu 2009; Lee and Wei 2010). However, many firms are unable to use this process because of the high expense of Six Sigma training. Another issue is how long it seems to take to implement Six Sigma and start seeing results (Timans et al. 2012; Albliwi, Antony, and Lim 2015).

As a result, when Lean and Six Sigma used together, they can make up for their shortcomings when used separately (Bhuiyan, Baghel, and Wilson 2006; Albliwi, Antony, and Lim 2015). Additionally, combining them can increase performance more quickly than using each strategy separately (Salah, Rahim, and Carretero 2010; Laureani and Antony 2012; Timans et al. 2012; Albliwi, Antony, and Lim 2015). As a result, Lean and Six Sigma complement one another nicely (Hu et al. 2008; Shahin and Alinavaz 2008). In conclusion, combining the techniques of Lean and Six Sigma enhances the performance of both industrial and service businesses (Laureani and Antony 2012). According to Lee and Wei (2010) and Chen and Lyu (2009), the LSS technique strives to improve organizational competency while lowering production costs and raising quality (Laureani and Antony 2012). Also, according to several authors (Ahmed, Page, and Olsen 2019; Parmar and Desai 2019; Panayiotou and Stergiou 2021) more hybrid models need to be created within LSS to produce the most accurate results that accurately reflect reality.

However, a lot of researchers (Antony, Escamilla, and Caine 2003; Kumar et al. 2006; Langabeer et al. 2009; Thomas, Barton, and Okafor 2008; Snee 2010; Franchetti and Yanik 2011; Chakravorty and Shah 2012; Maleyeff, Arnheiter, and Venkateswaran 2012; Timans et al. 2012; Vinodh, Kumar, and Vimal 2014; Bossert 2013) noted that various factors are impeding the application of LSS in the manufacturing sector. In addition, Alblooshi et al. (2021) discovered that LSS has a second impact category that pertains to organizational and individual behaviors. Training, organizational culture, and management commitment were found to be some of the most vital elements for effective LSS implementations. In addition, it was found that the most prevalent types of implementation challenges all included a lack of understanding of LSS tools and advantages, a lack of change management, and resistance to change.

Therefore, the identification of key success factors (CSFs) for the adoption of LSS showed great attention to several authors (Laureani and Antony 2012; Näslund 2013; Albliwi et al. 2014; Krueger, Parast, and Adams 2014; Lertwattanapongchai and Swierczek 2014) who presented different CSF that led to LSS deployment failures.

Panayiotou, Stergiou, and Panagiotou (2022) revealed that companies can attain benefits by

accomplishing certain CSFs for the fulfillment of the LSS project, also the improvements of LSS projects can be measured using metrics which can indirectly be translated into monetary terms. Therefore, to guarantee the success of any CI programme, it is crucial to identify the CSFs, as doing so enables firms to focus their efforts on these elements (Lane 2008; Laureani and Antony 2012; Tsironis and Psychogios 2016).

Hence, the researcher summarizes the CSFs for LSS implementation which has been identified in the literature as 18 factors (as shown in Table 1) to help organizations emphasize their efforts on these factors (Lane 2008; Laureani and Antony 2012; Tsironis and Psychogios 2016) within Egyptian culture, manufacturing industry, and different economy than tested before.

Later, Strubelt and Mollenhauer (2019) declared that the integration of communities of practice, information and communication technologies, and feedback and "lessons learned" sessions can develop potentially positive synergy effects and contribute positively to the success of LSS projects. Hence, automation in production has played an important role and Industry 4.0 allows to advance in this field. Additionally, Jayaram (2016) declared that LSS approach in global SC using Industry 4.0 and Industrial internet of things creates an ideal process flow that is highly optimized as well as perfect and free from defects and wastage.

Table 1. LSS critical success factor implementation.

Serial	Item
1.	Linking the strategic objectives of the organization to long-term planning
2.	Focusing on business (customer) results
3.	Top management support
4.	Leadership has vision and is capable of leading
5.	Organizational procedures and policies based on defined responsibilities and duties of its employees
6.	Organizational culture fit with Lean Six Sigma implementation
7.	Organizational vision communicated to all employees
8.	Organization gives rewards and appreciation to employees for meeting a pre-determined goal
9.	Employees committed to the organization
10.	Utilizing the necessary techniques, strategies, knowledge, abilities, and experience to achieve the project's goals.
11.	The organization demonstrates the need for change
12.	Work activities are organized around teams rather than individuals
13.	Commitment and communication between an organization and its employees
14.	Providing Training to employees
15.	Providing information technology support
16.	Explaining activities and releasing the results in a transparent manner
17.	Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets.
18.	Considering the final result or outcome

Industry 4.0

Academics, corporate executives, and producers are paying more attention to the fourth industrial revolution (Tortorella, Giglio, and van Dun 2019). The term "new manufacturing epoch" was first used by the German federal government in a 2011 presentation at the Hannover Messe. The intention was to transform industries by integrating digital and Internet technology with established businesses and to grow the German economy through high-tech strategies (Kannan and Garad 2020). It is a general word used to define the digital manufacturing system produced by the efficient combination of specific techniques, information technology, and production processes (Kamble, Gunasekaran, and Dhone 2020).

Sony (2018) mentioned that numerous researchers have paid close attention to advancing the idea of Industry 4.0 from its theoretical foundation to practical implementations by talking about its applications in many industries and a variety of factors linked to the I4.0 environment. However, according to McDermott et al. (2023), given the obstacles to I4.0, including its high prices, lack of government support, and concern over selecting the incorrect tools; a sizable majority of companies are not currently executing any I4.0 initiatives or include it in their strategies.

Therefore, some aspects, particularly in manufacturing companies in developing countries, may make the implementation of Industry 4.0 less successful. A general drop in technological intensity, a lack of accessible investment capital, and a lack of human resources are some of these contributing elements (Tortorella, Giglio, and van Dun 2019; Anderl 2014). For example, regarding Egypt, the Ministry of Communications and Information Technology and the Ministry of Trade and Industry witnessed the signing of a Memorandum of Understanding between the Industrial Modernization Center (IMC), Siemens Egypt, and the Information Technology Industry Development Agency (ITIDA), to establish and equip Egypt's first Industry 4.0 Innovation Center for encouraging industrial innovation and the development of intelligent factories in a way that encourages knowledge transfer and the growth of the regional industrial sector (Itida.gov 2021). However, most Egyptian firms are still transitioning or still need to transition from Industry 2.0 to Industry 3.0.

Adoption of I4.0 presents difficulties for businesses in the industrial sector (Frank, Dalenogare, and Ayala 2019). Despite I4.0's rising popularity, many businesses are still struggling to implement its cutting-edge methods into their everyday work (Sanders, Elangeswaran,

Table 2. I4.0 factors for implementation.

Serial	Item
1.	Digitize the organization
2.	Change management
3.	Managing cyber security
4.	Importance of employees
5.	Top management support
6.	Align the organizational strategy with the I4.0 efforts
7.	Digitize the supply chain
8.	Project management
9.	Make your goods and services intelligent
10.	Future of work and sustainability

and Wulfsberg 2016, Sanders et al. 2017; Erol et al. 2016; Tortorella, Giglio, and van Dun 2019). Therefore, Sony and Naik (2020) determined 10 key success elements that are necessary for I4.0 to be implemented successfully that can be used as a guide for firms to integrate I4.0 into their operations. Those critical success factor are: digitize the organization, change management, managing cyber security, importance of employees, top management support, align the organizational strategy with the I4.0 efforts, digitize the supply chain, project management, make your goods and services intelligent, and the future of work and sustainability. Table 2 illustrates and summarizes the mentioned factors.

LSS and I4.0

It has been noted from recent research that the industrial system is undergoing a significant paradigm shift in favor of smart manufacturing or I4.0 (Singh et al. 2021; Aguayo et al. 2022). Without a doubt, merging LSS with I4.0 is a significant research area that must be thoroughly investigated today, since LSS is a data-driven technology, the new industrial paradigm can offer the appropriate volume of illuminating data to support these quality improvement strategies. However, most studies have only focused on the relationship between I4.0 and Lean (Tissir et al. 2022).

Lean Management and Industry 4.0 integration was initially proposed by Tortorella and Fettermann (2018). There have been few studies on the importance of investigating the link between Lean Management and I4.0 (Buer, Strandhagen, and Chan 2018; Kolberg, Knobloch, and Zühlke 2017; Sanders, Elangeswaran, and Wulfsberg 2016; Sanders et al. 2017; Tortorella and Fettermann 2018; Buer, Strandhagen, and Chan 2018; Rosin et al. 2020). I4.0 and lean management both employ decentralized control and seek to boost efficiency and adaptability (Buer, Strandhagen, and Chan 2018). Later, Rosin et al. (2020) gave a summary of how I4.0 technology affected Lean principles by expected capacity levels. According to Alsadi et al. (2023), the idea of combining Lean Principles with I4.0 is still relatively new and limited. The integration is difficult as it covers a wide range of research topics without a bibliometric perspective. They conclude from their research that the field of Lean I4.0 lacks a generally accepted definition, and that further research is necessary to provide a definition. As well, according to Hines et al. (2023), researchers in the field of Lean I4.0 are typically from Europe and Asia and have background in engineering. The research also argues that the topic of Lean I4.0 lacks a generally accepted definition, highlighting the necessity of further research to provide a definition.

Similarly, Kim (2017) stated that utilizing the competencies of Six Sigma Master Black Belt can be a key to success in the I4.0 revolution.

Hence, the literature has indicated the need for more studies addressing the integration between I4.0 and LSS. According to Alsadi et al. (2023), the idea of combining Lean Principles with I4.0 is still relatively new and limited. The integration is difficult as it covers a wide range of research topics without a bibliometric perspective. They conclude from their research that the field of Lean I4.0 lacks a generally accepted definition, and that further research is necessary to provide a definition.

Bhat, Bhat, and Gijo (2021) demonstrated that LSS may be employed in the early phases of I4.0 by adopting data analysis through simulation while embracing the current strategy, with an emphasis on automation in the process industry. Additionally, Aguayo et al. (2022) identified Twenty integration barriers, highlighting the high implementation cost, long learning curve, and technology incompatibility as the main barriers. And Seventeen enablers were found to facilitate and guarantee implementation success, highlighting investment in IT infrastructure and employee training, stakeholder involvement, and top management support. Moreover, Sordan et al. (2022) presented a conceptual framework covering 13 contact points between LSS practices and I4.0 that can assist operational excellence projects toward digitalization.

The common themes for integrating I4.0 with quality-related operational excellence approaches are examined by Komkowski et al. (2023). To give a practical viewpoint when carrying out their integration and execution, their study focuses on the "what" and "how" level of total quality management, Lean Six Sigma, and business process management as quality related operational excellence approaches connected with I4.0.

The impact of I4.0 technologies on LSS, the connection between LM, SS, and I4.0, and the

consequences of their combination on operational excellence were noted by Skalli et al. (2023). The findings demonstrate that most scholars believe that I4.0 is a driver of LSS and a requirement for assisting businesses in accessing the necessary data and analytics. Skalli et al. (2023) added that Europe is by far the leading continent in scientific discussion and studies on the integration of I4.0 and LSS headed by Germany and Italy, while developing countries are less involved.

Antony, Tortorella, and Sony (2023a) added that, to achieve a new level of operational excellence and superior performance in terms of quality and reliability, manufacturers are incorporating new technologies into their production facilities and across their operations. Hence, operational excellence approaches, such as LSS, must be successfully linked with I4.0 technologies to achieve a sustainable competitive advantage.

However, research on the integration of LSS with Industry 4.0 is still lacking, particularly in emerging nations like Egypt. Hence, this research is intended to address this research gap by developing a theoretical integration model between LSS and I4.0. This will be done by investigating the LSS CSF implementation, as well, the CSF for I4.0 implementation to assess the CSF for I4 inside Egyptian culture, manufacturing industry, and different economies than tried before.

Research method

This research employs the concept of a systematic literature review, which guarantees replication by employing clear stages. A thorough basis for future research is laid by a systematic review, which also makes it easier to create theories, aligns existing research, and identifies areas in which more study is required (Webster and Watson 2002; Tranfield, Denyer, and Palminder 2003). The literature searches were conducted through the academic databases Scopus, ProQuest, Web of Science, Emerald Insight, and Science Direct for any related topics to LSS and I4.0. Only peer-reviewed academic journal articles, conference articles, and book sections were considered, to establish inclusion and exclusion criteria that ensures an objective reasoning behind the choice of literature (Meline 2006).

Additionally, the aim of this study is to explore how I4.0 and LSS might be integrated to enhance organizational effectiveness and efficiency, it could be classed as exploratory and deductive. Survey research was selected for analytical validation out of the exploratory nature of this research. The information was collected with an offline structured questionnaire, where the author visited the sites and collected responses from employees working in different departments of quality, production, supply chain and IT. Multiple informants from each company have been used enhancing the validity of the research findings.

The sample was chosen based on a census of total population of manufacturing companies that are registered in the Industrial Modernization Center (IMC) database. The snowball sampling technique was used to reach to the sample size. This technique was used to reach the respondents as there was no sampling frame for the companies implementing industry 4.0 in the Egyptian context. Therefore, a non-probability sampling technique was chosen for the data collection. Also, the snowball sampling design was chosen as the author considered referrals from respondents to be able to complete the data collection process, where referral of the population of the sample as current participants are likely to know others who share similar characteristics that are relevant to the study.

The sample size is determined by Saunders equations (Saunders et al. 2016) for sample size of 95% confidence level for infinite number of population, as there is no sampling frame for the manufacturing industry in Egypt therefore, the non-probability sampling was utilized. Therefore, a minimum number of 385 respondents were targeted. A number of 1500 questionnaires were distributed, but only a number of 963 questionnaires were collected, with a response rate of 64.2%. Finally, only 733 questionnaires were considered in the analysis, after deleting invalid or missing questionnaires.

The questionnaire was utilized for collecting data in 244 factories from 733 employees at one point during the period from December 2021 to June 2022 to respond to the importance of different critical success factors for both; LSS and I4.0 based on their knowledge. The questionnaire consists of three parts: The first part seeks demographic data including participant name (optional), gender, age, and the type of organization (as shown in 3). The second part uses the following scale to assess respondents' perceptions of the present CSF for integrating I4.0 and the LSS within their businesses. I disagree with (1) and support (5). The survey's final question asked respondents to rate their likelihood that LSS and I4.0 would be implemented in their organizations on a five-point Likert scale, with responses ranging from (1) strongly not implemented to (5) strongly implemented. The questionnaire statements were developed from previous studies (Chiarini and Kumar 2021; Antony et al. 2023b; Letchumanan et al. 2022).

The research unit of analysis is the companies' employees, where employees selected for questionnaires are those working in quality, supply, production, and IT within the Egyptian manufacturing industries, as they are considered the major source of information to achieve the research purpose.

According to such selection criteria, a pilot study was handled after collecting 60 questionnaires, where validity is tested for construct by face and content validity, as well reliability testing. Amendments were done according to the results obtained and then validity and reliability were retested after collecting the whole sample under study. The results of the validity and reliability for the whole sample are illustrated in Table 3, as shown below. It could be noticed that values of average variance extracted are all greater than 50%, representing that statements are relevant to the construct under study. In addition, all factor loadings exceed 0.4, which means that they have good contribution in forming their constructs. Moreover, all Cronbach's alpha values are greater than 0.7, which means that the statements are consistent within each respondent.

Then, the previous results of the validity and reliability provided evidence for the validity and reliability of the questionnaire under study. Also, the respondents' profile is illustrated in Table 4, where respondents are asked about their gender, age group, the sector where their organization belongs to, the number of employees in their organizations, and if they heard about industry 4.0.

Table 3. Validity and reliability of the research variables.

Factors	Symbols	Factor Loading	AVE	Cronbach Alpha
LSS1	**LSS 1.1**	0.905	90.471%	0.885
	LSS 1.2	0.905		
LSS2	**LSS 2.1**	0.929	92.920%	0.919
	LSS 2.2	0.929		
LSS3	**LSS 3.1**	0.847	84.740%	0.794
	LSS 3.2	0.847		
LSS4	**LSS 4.1**	0.929	92.920%	0.919
	LSS 4.2	0.929		
LSS5	**LSS 5.1**	0.929	92.920%	0.919
	LSS 5.2	0.929		
LSS6	**LSS 6.1**	0.905	90.471%	0.885
	LSS 6.2	0.905		
LSS7	**LSS 7.1**	0.847	84.740%	0.794
	LSS 7.2	0.847		
LSS8	**LSS 8.1**	0.905	90.471%	0.885
	LSS 8.2	0.905		
LSS9	**LSS 9.1**	0.847	84.740%	0.794
	LSS 9.2	0.847		
LSS10	**LSS 10.1**	0.880	88.044%	0.851
	LSS 10.2	0.880		
LSS11	**LSS 11.1**	0.905	90.471%	0.885
	LSS 11.2	0.905		
LSS12	**LSS 12.1**	0.919	91.914%	0.912
	LSS 12.2	0.919		
LSS13	**LSS 13.1**	0.905	90.471%	0.885
	LSS 13.2	0.905		
LSS14	**LSS 14.1**	0.873	87.275%	0.852
	LSS 14.2	0.873		
LSS15	**LSS 15.1**	0.905	90.471%	0.885
	LSS 15.2	0.905		
LSS16	**LSS 16.1**	0.822	82.233%	0.781
	LSS 16.2	0.822		
LSS17	**LSS 17.1**	0.929	92.920%	0.919
	LSS 17.2	0.929		
LSS18	**LSS 18.1**	0.907	90.741%	0.898
	LSS 18.2	0.907		

Results and findings

This section introduces the empirical study with the main findings and results after running the data analysis. A descriptive analysis is presented for research variables. Correlation and regression analyses are used to test LSS factors that could affect the I4.0 implementation. The analysis is conducted using SPSS.

Descriptive analysis

Table 5 shows the mean and standard deviation for the LSS and I4.0 critical success factors. It could be observed that the mean and the frequencies of most responses for the LSS are in the agreement zone, as the mean values for LSS factors range between 3.4229 and 3.8799. Similarly, the mean values for I4.0 range between 3.8581 and 4.1228. Moreover, it is noticed that there are a lot of employees who didn't hear about I4.0 concepts, which shows that it is still not well-known topic within Egyptian context.

Table 4. Descriptive statistics for respondents profile.

Item	Frequency	Percentage	Total
Gender			
Male	617	84.17%	733
Female	116	15.83%	
Age Group			
Less than 40 years	435	59.35%	733
40 – less than 50 years	206	28.10%	
50 – less than 60 years	42	5.73%	
60 years or more	50	6.82%	
Sector			
Food	87	11.87%	733
Automotive & spare parts	89	12.14%	
Iron & Steel	88	12.01%	
Pharma	92	12.55%	
Oil/Gas	96	13.10%	
Chemical	72	9.82%	
Electronics & Electrics	101	13.78%	
Other Industries	108	14.73%	
Number of Employees			
Between 0 and 9 Employees	196	26.74%	733
Between 10 and 49 Employees	377	51.43%	
Between 50 and 249 Employees	127	17.33%	
>250 Employees	33	4.50%	
Have you heard of the industry 4.0 concept?			
Yes	552	75.31%	733
No	181	24.69%	

Examining the integration between LSS and I4.0 implementation

In this section, the hypotheses under study are tested using the correlation and regression. Table 6 shows the correlation matrix for the relationship between LSS Critical Success Factor and First Critical Factor. It was observed that there is a significant positive relationship between all LSS factors and all I4.0 factors, as the corresponding P-values are all less than 0.05 and the corresponding correlation coefficients are greater than zero (P-value < 0.05; $r>0$).

Table 7 shows the regression analysis for the impact of the LSS critical success factors on I4.0 critical success factors for implementation. It could be observed that there is a significant impact of LSS3, LSS4, LSS5, LSS6, LSS9, LSS11, LSS12, LSS13, LSS15, LSS16, LSS17, LSS18 on I4.0:1, as the corresponding P-values are all less than 0.05 and the regression coefficients are greater than zero (P-value < 0.05; $r>0$). On the other hand, there is an insignificant impact of LSS1, LSS2, LSS7, LSS8, LSS10, LSS14 on I4.0:1, as the corresponding P-values are greater than 0.05 (P-value > 0.05). Furthermore, the R square is 0.791, which means 79.1% of the variation in I4.0:1 can be explained by the LSS critical success factors. The importance of LSS critical success factors with respect to I4.0:1 could be ranked as the standardized estimate as follows; LSS18 is the first, with a standardized estimate of 0.225, the second is LSS17 with a standardized estimate of 0.208, the third is LSS11 with a standardized estimate of 0.156, the fourth is LSS16 with a standardized estimate of 0.146, the fifth is LSS13 with a standardized estimate of 0.105, the sixth is LSS4 with a standardized estimate of 0.094, the seventh is LSS6 with a standardized estimate of 0.089, the eighth is LSS15 with a standardized estimate of 0.086, the ninth is LSS5 with a standardized estimate of 0.081, the tenth is LSS3 with a standardized estimate of 0.076, the eleventh is LSS9 with a standardized estimate of 0.069, the twelfth is LSS12 with a standardized estimate of 0.048.

Table 5. Descriptive analysis for the LSS and I4.0 CSF of implementation.

				Frequencies				
Variables	N	Mean	Std. Deviation	1	2	3	4	5
LSS1	733	3.6712	.86820	0	59	259	279	136
LSS2	733	3.6248	.89917	0	66	287	236	144
LSS3	733	3.6630	.80620	0	34	301	276	122
LSS4	733	3.7763	.74411	0	12	267	327	127
LSS5	733	3.6821	.80549	0	18	337	238	140
LSS6	733	3.7422	.83328	0	39	256	293	145
LSS7	733	3.7053	.81344	0	41	259	308	125
LSS8	733	3.6521	.70545	0	19	297	337	80
LSS9	733	3.7121	.77200	0	19	297	293	124
LSS10	733	3.5198	.65803	0	5	404	262	62
LSS11	733	3.5812	.66573	0	5	365	295	68
LSS12	733	3.4229	.61058	0	11	437	249	36
LSS13	733	3.5348	.66362	0	4	399	264	66
LSS14	733	3.5798	.76696	0	27	353	254	99
LSS15	733	3.5157	.66844	0	7	406	255	65
LSS16	733	3.8336	.72211	0	11	229	364	129
LSS17	733	3.8799	.78531	0	12	239	307	175
LSS18	733	3.8581	.78862	0	3	278	272	180
CSF1	733	3.9686	.79469	0	0	243	270	220
CSF2	733	4.1228	.73454	0	0	158	327	248
CSF3	733	3.9318	.76875	0	0	243	297	193
CSF4	733	4.0914	.71754	0	0	158	350	225
CSF5	733	4.0628	.55209	0	0	90	507	136
CSF6	733	3.8581	.70831	0	0	243	351	139
CSF7	733	3.9714	.65745	0	0	169	416	148
CSF8	733	3.9195	.58236	0	0	156	480	97
CSF9	733	4.0164	.74823	0	0	199	323	211
CSF10	733	3.9563	.68811	0	0	190	385	158

In addition, it could be observed that there is a significant impact of LSS5, LSS6, LSS11, LSS12, LSS13, LSS15, LSS16, LSS17, LSS18 on I4.0:2, as the corresponding P-values are all less than 0.05 and the regression coefficients are greater than zero (P-value < 0.05; $r>0$). On the other hand, there is an insignificant impact of LSS1, LSS2, LSS3, LSS4, LSS7, LSS8, LSS9, LSS10, LSS14 on I4.0:2, as the corresponding P-values are greater than 0.05 (P-value > 0.05). Furthermore, the R square is 0.718, which means 71.8% of the variation in I4.0:2 can be explained by the LSS critical success factors. The importance of LSS critical success factors with respect to I4.0:2 could be ranked as the standardized estimate as follows; the first is LSS17 with a standardized estimate of 0.247, the second is LSS18 with a standardized estimate of 0.204, the third is LSS16 with a standardized estimate of 0.167, the fourth is LSS11 with a standardized estimate of 0.117, the fifth is LSS5 with a standardized estimate of 0.094, the sixth is LSS6 with a standardized estimate of 0.086, the seventh is LSS13 with a standardized estimate of 0.084, the eighth is LSS12 with a standardized estimate of 0.064, the ninth is LSS15 with a standardized estimate of 0.064.

It could also be noticed that there is a significant impact of LSS4, LSS9, LSS11, LSS13, LSS14, LSS15, LSS16, LSS17, LSS18 on I4.0:3, as the corresponding P-values are all less than 0.05 and the regression coefficients are greater than zero (P-value < 0.05; $r>0$). On the other hand, there is an insignificant impact of LSS1, LSS2, LSS3, LSS5, LSS6, LSS7, LSS8, LSS10, LSS12 on I4.0:3, as the corresponding P-values are greater than 0.05 (P-value > 0.05). Furthermore, the R square is 0.524, which means 52.4% of the variation in I4.0:3 can be explained by the LSS critical success factors. The importance of LSS critical success factors with respect to I4.0:3 could be ranked as the standardized estimate as follows; the first is LSS18 with a standardized estimate of 0.162, the second is LSS11 with a standardized estimate of 0.147,

Table 6. Correlation matrix between LSS CSFs and first critical factor.

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.
1. LSS1	r	1																		
	P-value																			
2. LSS2	r	.722**	1																	
	P-value	.000																		
3. LSS3	r	.466**	.549**	1																
	P-value	.000	.000																	
4. LSS4	r	.364**	.411**	.361**	1															
	P-value	.000	.000	.000																
5. LSS5	r	.220**	.273**	.344**	.567**	1														
	P-value	.000	.000	.000	.000															
6. LSS6	r	.442**	.476**	.393**	.508**	.509**	1													
	P-value	.000	.000	.000	.000	.000														
7. LSS7	r	.544**	.495**	.344**	.525**	.434**	.664**	1												
	P-value	.000	.000	.000	.000	.000	.000													
8. LSS8	r	.344**	.332**	.461**	.434**	.483**	.440**	.481**	1											
	P-value	.000	.000	.000	.000	.000	.000	.000												
9. LSS9	r	.372**	.376**	.527**	.401**	.485**	.505**	.476**	.646**	1										
	P-value	.000	.000	.000	.000	.000	.000	.000	.000											
10. LSS10	r	.376**	.337**	.228**	.068	−.062	.135**	.184**	.105**	.177**	1									
	P-value	.000	.000	.000	.067	.096	.000	.000	.005	.000										
11. LSS11	r	.338**	.346**	.330**	.277**	.241**	.317**	.276**	.268**	.267**	.261**	1								
	P-value	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000									
12. LSS12	r	.379**	.376**	.340**	.215**	.099**	.271**	.276**	.209**	.276**	.462**	.399**	1							
	P-value	.000	.000	.000	.000	.007	.000	.000	.000	.000	.000	.000								
13. LSS13	r	.367**	.344**	.314**	.270**	.150**	.245**	.290**	.237**	.264**	.529**	.384**	.611**	1						
	P-value	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000							
14. LSS14	r	.375**	.393**	.288**	.206**	.124**	.273**	.279**	.171**	.252**	.423**	.329**	.517**	.498**	1					
	P-value	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000						
15. LSS15	r	.276**	.279**	.361**	.232**	.168**	.264**	.189**	.291**	.352**	.381**	.452**	.549**	.505**	.429**	1				
	P-value	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000					
16. LSS16	r	.318**	.350**	.354**	.437**	.400**	.333**	.307**	.414**	.377**	.156**	.329**	.305**	.346**	.224**	.373**	1			
	P-value	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000				
17. LSS17	r	.349**	.387**	.368**	.501**	.477**	.410**	.417**	.405**	.434**	.124**	.361**	.294**	.252**	.306**	.363**	.540**	1		
	P-value	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000			
18. LSS18	r	.341**	.387**	.419**	.465**	.490**	.400**	.361**	.442**	.451**	.155**	.350**	.329**	.276**	.256**	.421**	.573**	.647**	1	
	P-value	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		
19. CSF1	r	.365**	.431**	.512**	.563**	.550**	.508**	.417**	.504**	.544**	.232**	.535**	.455**	.459**	.366**	.547**	.648**	.703**	.738**	1
	P-value	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
20. CSF2	r	.372**	.446**	.483**	.523**	.526**	.489**	.406**	.467**	.511**	.227**	.494**	.445**	.434**	.375**	.508**	.631**	.693**	.695**	1
	P-value	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
21. CSF3	r	.398**	.392**	.424**	.427**	.360**	.395**	.354**	.369**	.439**	.275**	.467**	.382**	.436**	.422**	.489**	.511**	.539**	.552**	1
	P-value	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
22. CSF4	r	.309**	.369**	.469**	.532**	.525**	.476**	.390**	.468**	.509**	.171**	.472**	.395**	.391**	.281**	.485**	.620**	.677**	.694**	1
	P-value	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
23. CSF5	r	.251**	.254**	.391**	.367**	.328**	.282**	.245**	.361**	.369**	.162**	.376**	.298**	.326**	.175**	.368**	.465**	.503**	.541**	1
	P-value	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
24. CSF6	r	.417**	.448**	.447**	.386**	.337**	.396**	.323**	.399**	.402**	.308**	.514**	.455**	.493**	.426**	.539**	.531**	.512**	.544**	1
	P-value	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
25. CSF7	r	.326**	.384**	.374**	.367**	.339**	.313**	.255**	.317**	.352**	.249**	.428**	.347**	.395**	.336**	.441**	.450**	.467**	.501**	1
	P-value	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
26. CSF8	r	.329**	.307**	.396**	.381**	.318**	.391**	.331**	.414**	.447**	.252**	.431**	.384**	.405**	.297**	.423**	.481**	.514**	.537**	1
	P-value	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
27. CSF9	r	.338**	.399**	.392**	.407**	.340**	.381**	.322**	.350**	.344**	.296**	.488**	.472**	.469**	.412**	.491**	.463**	.466**	.513**	1
	P-value	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
28. CSF10	r	.374**	.408**	.454**	.464**	.414**	.414**	.341**	.441**	.462**	.249**	.509**	.457**	.461**	.356**	.503**	.532**	.577**	.613**	1
	P-value	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	

**Correlation is significant at the 0.01 level (2-tailed).

Table 7. Regression model of LSS CSFs on Industry 4.0 CSFs.

LSS	I4.0 CSFs									
CSFs	I4:1	I4:2	I4:3	I4:4	I4:5	I4:6	I4:7	I4:8	I4:9	I4:10
LSS1	−.086	−.074	.073	−.095	.002	.043	−.009	.029	−.068	.001
LSS2	−.011	.043	−.056	−.040	−.109	.061	.103*	−.132	.061	.007
LSS3	.076**	.052	.058	.086**	.143**	.052	.028	.062	.036	.048
LSS4	.094**	.045	.076**	.088**	.066	.001	.052	.042	.083*	.086*
LSS5	.081**	.098**	−.013	.068*	−.036	.001	.065	−.097	.035	.016
LSS6	.089**	.086**	.041	.096**	−.002	.078*	.003	.117**	.071	.056
LSS7	−.066	−.062	−.032	−.041	−.062	−.100	−.107	−.053	−.046	−.012
LSS8	.011	−.003	−.043	−.009	.034	.062	−.012	.066	.042	.058
LSS9	.069**	.055	.095**	.072*	.045	−.011	.034	.113**	−.057	.061
LSS10	−.003	−.007	.011	−.018	.007	−.005	.024	.037	.024	−.022
LSS11	.156**	.117**	.147**	.126**	.131**	.172**	.147**	.147**	.175**	.176**
LSS12	.048**	.064**	−.077	.055	.017	−.003	−.043	.037	.097*	.081*
LSS13	.105**	.084**	.111**	.088**	.130**	.150**	.124*	.134**	.117**	.142**
LSS14	.000	.027	.138**	−.057	−.106	.083**	.053**	−.013	.089*	.001
LSS15	.086**	.064**	.112**	.075**	.020	.140**	.112**	.009	.094*	.067*
LSS16	.146**	.167**	.134**	.163**	.103**	.152**	.096*	.110**	.086*	.081*
LSS17	.208**	.247**	.134**	.237**	.195**	.100**	.108*	.169**	.057	.157**
LSS18	.255**	.204**	.162**	.232**	.242**	.134**	.163**	.194**	.160**	.206**
R^2	0.791	0.718	0.524	0.697	0.419	0.562	0.415	0.469	0.492	0.591

the third is LSS14 with a standardized estimate of 0.138, the fourth is LSS16 with a standardized estimate of 0.134, the fifth is LSS17 with a standardized estimate of 0.134, the sixth is LSS15 with a standardized estimate of 0.112, the seventh is LSS13 with a standardized estimate of 0.111, the eighth is LSS9 with a standardized estimate of 0.095, the ninth is LSS4 with a standardized estimate of 0.076.

Moreover, it could be noticed that there is a significant impact of LSS3, LSS4, LSS5, LSS6, LSS9, LSS11, LSS13, LSS15, LSS16, LSS17, LSS18 on I4.0:4, as the corresponding P-values are all less than 0.05 and the regression coefficients are greater than zero (P-value < 0.05; $r>0$). On the other hand, there is an insignificant impact of LSS1, LSS2, LSS7, LSS8, LSS10, LSS12, LSS14 on I4.0:4, as the corresponding P-values are greater than 0.05 (P-value > 0.05). Furthermore, the R square is 0.697, which means 69.7% of the variation in I4.0:4 can be explained by the LSS critical success factors. The importance of LSS critical success factors with respect to I4.0:4 could be ranked as the standardized estimate as follows; the first is LSS17 with a standardized estimate of 0.237, the second is LSS18 with a standardized estimate of 0.232, the third is LSS16 with a standardized estimate of 0.163, the fourth is LSS11 with a standardized estimate of 0.126, the fifth is LSS6 with a standardized estimate of 0.096, the sixth is LSS4 with a standardized estimate of 0.088, the seventh is LSS13 with a standardized estimate of 0.088, the eighth is LSS3 with a standardized estimate of 0.086, the ninth is LSS15 with a standardized estimate of 0.075, the tenth is LSS9 with a standardized estimate of 0.072, the eleventh is LSS5 with a standardized estimate of 0.068.

Furthermore, it could be noticed that there is a significant impact of LSS3, LSS11, LSS13, LSS16, LSS17, LSS18 on I4.0:5, as the corresponding P-values are all less than 0.05 and the regression coefficients are greater than zero (P-value < 0.05; $r>0$). On the other hand, there is an insignificant impact of LSS1, LSS2, LSS4, LSS5, LSS6, LSS7, LSS8, LSS9, LSS10, LSS12, LSS14, LSS15 on I4.0:5, as the corresponding P-values are greater than 0.05 (P-value > 0.05). Furthermore, the R square is 0.419, which means 41.9% of the variation in I4.0:5 can be explained by the LSS critical success factors. The importance of LSS critical success factors with respect to I4.0:5 could be ranked as the standardized estimate as follows; the first is LSS18 with a standardized estimate of 0.242, the second is LSS17 with a standardized estimate of 0.195, the third is LSS3 with a standardized estimate of 0.143, the fourth is LSS11 with a standardized estimate of 0.131, the fifth is LSS13 with a standardized estimate of 0.130, the sixth is LSS16 with a standardized estimate of 0.103.

Besides, it could be noticed that there is a significant impact of LSS6, LSS11, LSS13, LSS14, LSS15, LSS16, LSS17, LSS18 on I4.0:6, as the corresponding P-values are all less than 0.05 and the regression coefficients are greater than zero (P-value < 0.05; $r>0$). On the other hand, there is an insignificant impact of LSS1, LSS2, LSS3, LSS4, LSS5, LSS7, LSS8, LSS9, LSS10, LSS12 on I4.0:6, as the corresponding P-values are greater than 0.05 (P-value > 0.05). Furthermore, the R square is 0.562, which means 56.2% of the variation in I4.0:6 can be explained by the LSS critical success factors. The importance of LSS critical success factors with respect to I4.0:6 could be ranked as the standardized estimate as follows; the first is LSS11 with a standardized estimate of 0.172, the second is LSS16 with a standardized estimate of 0.152, the third is LSS13 with a standardized estimate of 0.150, the fourth is LSS15 with a

standardized estimate of 0.140, the fifth is LSS18 with a standardized estimate of 0.134, the sixth is LSS17 with a standardized estimate of 0.100, the seventh is LSS14 with a standardized estimate of 0.083, the eighth is LSS6 with a standardized estimate of 0.078.

Also, it could be noticed that there is a significant impact of LSS2, LSS11, LSS13, LSS14, LSS15, LSS16, LSS17, LSS18 on I4.0:7, as the corresponding P-values are all less than 0.05 and the regression coefficients are greater than zero (P-value < 0.05; $r>0$). On the other hand, there is an insignificant impact of LSS1, LSS3, LSS4, LSS5, LSS6, LSS7, LSS8, LSS9, LSS10, LSS12 on I4.0:7, as the corresponding P-values are greater than 0.05 (P-value > 0.05). Furthermore, the R square is 0.415, which means 41.5% of the variation in I4.0:7 can be explained by the LSS critical success factors. The importance of LSS critical success factors with respect to I4.0:7 could be ranked as the standardized estimate as follows; the first is LSS18 with a standardized estimate of 0.163, the second is LSS11 with a standardized estimate of 0.147, the third is LSS13 with a standardized estimate of 0.124, the fourth is LSS15 with a standardized estimate of 0.112, the fifth is LSS17 with a standardized estimate of 0.108, the sixth is LSS2 with a standardized estimate of 0.103, the seventh is LSS16 with a standardized estimate of 0.096, the eighth is LSS14 with a standardized estimate of 0.053.

In addition, it could be noticed that there is a significant impact of LSS6, LSS9, LSS11, LSS13, LSS14, LSS15, LSS16, LSS17, LSS18 on I4.0:8, as the corresponding P-values are all less than 0.05 and the regression coefficients are greater than zero (P-value < 0.05; $r>0$). On the other hand, there is an insignificant impact of LSS1, LSS2, LSS3, LSS4, LSS5, LSS7, LSS8, LSS10, LSS12 on I4.0:8, as the corresponding P-values are greater than 0.05 (P-value > 0.05). Furthermore, the R square is 0.469, which means 46.9% of the variation in I4.0:8 can be explained by the LSS critical success factors. The importance of LSS critical success factors with respect to I4.0:8 could be ranked as the standardized estimate as follows; the first is LSS18 with a standardized estimate of 0.194, the second is LSS17 with a standardized estimate of 0.169, the third is LSS11 with a standardized estimate of 0.147, the fourth is LSS13 with a standardized estimate of 0.134, the fifth is LSS6 with a standardized estimate of 0.117, the sixth is LSS9 with a standardized estimate of 0.113, the seventh is LSS16 with a standardized estimate of 0.110.

Moreover, it could be noticed that there is a significant impact of LSS4, LSS11, LSS12, LSS13, LSS14, LSS15, LSS16, LSS18 on I4.0:9, as the corresponding P-values are all less than 0.05 and the regression coefficients are greater than zero (P-value < 0.05; $r>0$). On the other hand, there is an insignificant impact of LSS1, LSS2, LSS3, LSS5, LSS6, LSS7, LSS8, LSS9, LSS10, LSS17 on I4.0:9, as the corresponding P-values are greater than 0.05 (P-value > 0.05). Furthermore, the R square is 0.492, which means 49.2% of the variation in I4.0:9 can be explained by the LSS critical success factors. The importance of LSS critical success factors with respect to I4.0:9 could be ranked as the standardized estimate as follows; the first is LSS11 with a standardized estimate of 0.175, the second is LSS18 with a standardized estimate of 0.160, the third is LSS13 with a standardized estimate of 0.117, the fourth is LSS12 with a standardized estimate of 0.097, the fifth is LSS15 with a standardized estimate of 0.094, the sixth is LSS14 with a standardized estimate of 0.089, the seventh is LSS16 with a standardized estimate of 0.086, the eighth is LSS4 with a standardized estimate of 0.083.

Finally, it could be noticed that there is a significant impact of LSS4, LSS11, LSS12, LSS13, LSS15, LSS16, LSS17, LSS18 on I4.0:10, as the corresponding P-values are all less than 0.05 and the regression coefficients are greater than zero (P-value < 0.05; $r>0$). On the other hand, there is an insignificant impact of LSS1, LSS2, LSS3, LSS5, LSS6, LSS7, LSS8, LSS9, LSS10, LSS14 on I4.0:9, as the corresponding P-values are greater than 0.05 (P-value > 0.05). Furthermore, the R square is 0.591, which means 59.1% of the variation in I4.0:9 can be explained by the LSS critical success factors. The importance of LSS critical success factors with respect to I4.0:10 could be ranked as the standardized estimate as follows; the first is LSS18 with a standardized estimate of 0.206, the second is LSS11 with a standardized estimate of 0.176, the third is LSS17 with a standardized estimate of 0.157, the fourth is LSS13 with a standardized estimate of 0.142, the fifth is LSS4 with a standardized estimate of 0.086, the sixth is LSS16 with a standardized estimate of 0.081, the seventh is LSS12 with a standardized estimate of 0.081, the eighth is LSS15 with a standardized estimate of 0.067.

ANOVA test for research variables

Table 8 shows the ANOVA test for the difference between Number of Employees. It shows that there is an insignificant difference of LSS critical success factor implementation, and I4.0 CSF of Implementation, as the corresponding P-values are more than 0.05.

Table 9 shows the Anova test for the difference between Sectors. It shows that there is an insignificant difference of LSS critical success factor

Table 8. ANOVA analysis for number of employees.

Variables	Number of Employees	N	Mean	P-value
LSS1	Between 0 and 9 Employees	196	3.6327	.697
	Between 10 and 49 Employees	377	3.6950	
	Between 50 and 249 Employees	127	3.6929	
	>250 Employees	33	3.5455	
	Total	733	3.6712	
LSS2	Between 0 and 9 Employees	196	3.6071	.578
	Between 10 and 49 Employees	377	3.6472	
	Between 50 and 249 Employees	127	3.6378	
	>250 Employees	33	3.4242	
	Total	733	3.6248	
LSS3	Between 0 and 9 Employees	196	3.6735	.988
	Between 10 and 49 Employees	377	3.6658	
	Between 50 and 249 Employees	127	3.6457	
	>250 Employees	33	3.6364	
	Total	733	3.6630	
LSS4	Between 0 and 9 Employees	196	3.7347	.654
	Between 10 and 49 Employees	377	3.7745	
	Between 50 and 249 Employees	127	3.8425	
	>250 Employees	33	3.7879	
	Total	733	3.7763	
LSS5	Between 0 and 9 Employees	196	3.6224	.476
	Between 10 and 49 Employees	377	3.7268	
	Between 50 and 249 Employees	127	3.6535	
	>250 Employees	33	3.6364	
	Total	733	3.6821	
LSS6	Between 0 and 9 Employees	196	3.7398	.971
	Between 10 and 49 Employees	377	3.7480	
	Between 50 and 249 Employees	127	3.7165	
	>250 Employees	33	3.7879	
	Total	733	3.7422	
LSS7	Between 0 and 9 Employees	196	3.6837	.952
	Between 10 and 49 Employees	377	3.7056	
	Between 50 and 249 Employees	127	3.7244	
	>250 Employees	33	3.7576	
	Total	733	3.7053	
LSS8	Between 0 and 9 Employees	196	3.6173	.749
	Between 10 and 49 Employees	377	3.6790	
	Between 50 and 249 Employees	127	3.6378	
	>250 Employees	33	3.6061	
	Total	733	3.6521	
LSS9	Between 0 and 9 Employees	196	3.6633	.575
	Between 10 and 49 Employees	377	3.7162	
	Between 50 and 249 Employees	127	3.7402	
	>250 Employees	33	3.8485	
	Total	733	3.7121	
LSS10	Between 0 and 9 Employees	196	3.4439	.053
	Between 10 and 49 Employees	377	3.5119	
	Between 50 and 249 Employees	127	3.6142	
	>250 Employees	33	3.6970	
	Total	733	3.5198	
LSS11	Between 0 and 9 Employees	196	3.5153	.397
	Between 10 and 49 Employees	377	3.6154	
	Between 50 and 249 Employees	127	3.5748	
	>250 Employees	33	3.6061	
	Total	733	3.5812	
LSS12	Between 0 and 9 Employees	196	3.3878	.242
	Between 10 and 49 Employees	377	3.4456	
	Between 50 and 249 Employees	127	3.3701	
	>250 Employees	33	3.5758	
	Total	733	3.4229	
LSS13	Between 0 and 9 Employees	196	3.4796	.372
	Between 10 and 49 Employees	377	3.5385	
	Between 50 and 249 Employees	127	3.5748	
	>250 Employees	33	3.6667	
	Total	733	3.5348	
LSS14	Between 0 and 9 Employees	196	3.5255	.496
	Between 10 and 49 Employees	377	3.5968	
	Between 50 and 249 Employees	127	3.5748	
	>250 Employees	33	3.7273	
	Total	733	3.5798	
LSS15	Between 0 and 9 Employees	196	3.5153	.352
	Between 10 and 49 Employees	377	3.5332	
	Between 50 and 249 Employees	127	3.4331	
	>250 Employees	33	3.6364	
	Total	733	3.5157	
LSS16	Between 0 and 9 Employees	196	3.8214	.953
	Between 10 and 49 Employees	377	3.8355	
	Between 50 and 249 Employees	127	3.8583	
	>250 Employees	33	3.7879	
	Total	733	3.8336	
LSS17	Between 0 and 9 Employees	196	3.9184	.544
	Between 10 and 49 Employees	377	3.8833	
	Between 50 and 249 Employees	127	3.7953	
	>250 Employees	33	3.9394	
	Total	733	3.8799	
LSS18	Between 0 and 9 Employees	196	3.8571	.171
	Between 10 and 49 Employees	377	3.8912	
	Between 50 and 249 Employees	127	3.8346	
	>250 Employees	33	3.5758	
	Total	733	3.8581	
CSF1	Between 0 and 9 Employees	196	3.9388	.870
	Between 10 and 49 Employees	377	3.9920	
	Between 50 and 249 Employees	127	3.9449	
	>250 Employees	33	3.9697	
	Total	733	3.9686	
CSF2	Between 0 and 9 Employees	196	4.1480	.852
	Between 10 and 49 Employees	377	4.1220	
	Between 50 and 249 Employees	127	4.1102	
	>250 Employees	33	4.0303	
	Total	733	4.1228	
CSF3	Between 0 and 9 Employees	196	3.9184	.661
	Between 10 and 49 Employees	377	3.9629	
	Between 50 and 249 Employees	127	3.8819	
	>250 Employees	33	3.8485	
	Total	733	3.9318	
CSF4	Between 0 and 9 Employees	196	4.0612	.690
	Between 10 and 49 Employees	377	4.1220	
	Between 50 and 249 Employees	127	4.0630	
	>250 Employees	33	4.0303	
	Total	733	4.0914	
CSF5	Between 0 and 9 Employees	196	4.0306	.662
	Between 10 and 49 Employees	377	4.0690	
	Between 50 and 249 Employees	127	4.0709	
	>250 Employees	33	4.1515	
	Total	733	4.0628	
CSF6	Between 0 and 9 Employees	196	3.8469	.993
	Between 10 and 49 Employees	377	3.8594	
	Between 50 and 249 Employees	127	3.8661	
	>250 Employees	33	3.8788	
	Total	733	3.8581	
CSF7	Between 0 and 9 Employees	196	3.9643	.947
	Between 10 and 49 Employees	377	3.9655	
	Between 50 and 249 Employees	127	3.9843	
	>250 Employees	33	4.0303	
	Total	733	3.9714	
CSF8	Between 0 and 9 Employees	196	3.8622	.406
	Between 10 and 49 Employees	377	3.9496	
	Between 50 and 249 Employees	127	3.9213	
	>250 Employees	33	3.9091	
	Total	733	3.9195	
CSF9	Between 0 and 9 Employees	196	4.0357	.955
	Between 10 and 49 Employees	377	4.0027	
	Between 50 and 249 Employees	127	4.0315	
	>250 Employees	33	4.0000	
	Total	733	4.0164	
CSF10	Between 0 and 9 Employees	196	3.9490	.952
	Between 10 and 49 Employees	377	3.9682	
	Between 50 and 249 Employees	127	3.9291	
	>250 Employees	33	3.9697	
	Total	733	3.9563	

(*Continued*)

Table 9. ANOVA analysis for sectors.

Variables	Sector	N	Mean	P-value
LSS1	Food	87	3.6322	.992
	Automotive & spare parts	89	3.7079	
	Iron & Steel	88	3.7045	
	Pharma	92	3.6304	
	Oil/Gas	96	3.6875	
	Chemical	72	3.6111	
	Electronics & Electrics	101	3.6931	
	Other Industries	108	3.6852	
	Total	733	3.6712	
LSS2	Food	87	3.6437	.782
	Automotive & spare parts	89	3.7303	
	Iron & Steel	88	3.6477	
	Pharma	92	3.5435	
	Oil/Gas	96	3.5833	
	Chemical	72	3.5000	
	Electronics & Electrics	101	3.6634	
	Other Industries	108	3.6574	
	Total	733	3.6248	
LSS3	Food	87	3.6782	.773
	Automotive & spare parts	89	3.6404	
	Iron & Steel	88	3.7159	
	Pharma	92	3.5978	
	Oil/Gas	96	3.6354	
	Chemical	72	3.5556	
	Electronics & Electrics	101	3.6832	
	Other Industries	108	3.7593	
	Total	733	3.6630	
LSS4	Food	87	3.7931	.868
	Automotive & spare parts	89	3.8427	
	Iron & Steel	88	3.7841	
	Pharma	92	3.6630	
	Oil/Gas	96	3.7708	
	Chemical	72	3.7500	
	Electronics & Electrics	101	3.8020	
	Other Industries	108	3.7963	
	Total	733	3.7763	
LSS5	Food	87	3.6322	.668
	Automotive & spare parts	89	3.7303	
	Iron & Steel	88	3.6250	
	Pharma	92	3.6304	
	Oil/Gas	96	3.6042	
	Chemical	72	3.6667	
	Electronics & Electrics	101	3.7822	
	Other Industries	108	3.7593	
	Total	733	3.6821	
LSS6	Food	87	3.6667	.927
	Automotive & spare parts	89	3.7416	
	Iron & Steel	88	3.7500	
	Pharma	92	3.7283	
	Oil/Gas	96	3.6875	
	Chemical	72	3.7639	
	Electronics & Electrics	101	3.7525	
	Other Industries	108	3.8333	
	Total	733	3.7422	
LSS7	Food	87	3.6207	.805
	Automotive & spare parts	89	3.6966	
	Iron & Steel	88	3.7386	
	Pharma	92	3.6087	
	Oil/Gas	96	3.7292	
	Chemical	72	3.7917	
	Electronics & Electrics	101	3.7624	
	Other Industries	108	3.7037	
	Total	733	3.7053	
LSS8	Food	87	3.6092	.999
	Automotive & spare parts	89	3.6404	
	Iron & Steel	88	3.6477	
	Pharma	92	3.6522	
	Oil/Gas	96	3.6667	
	Chemical	72	3.6528	
	Electronics & Electrics	101	3.6535	
	Other Industries	108	3.6852	
	Total	733	3.6521	
LSS9	Food	87	3.7011	.791
	Automotive & spare parts	89	3.7303	
	Iron & Steel	88	3.7500	
	Pharma	92	3.6413	
	Oil/Gas	96	3.6979	
	Chemical	72	3.5972	
	Electronics & Electrics	101	3.7822	
	Other Industries	108	3.7593	
	Total	733	3.7121	
LSS10	Food	87	3.4713	.180
	Automotive & spare parts	89	3.6517	
	Iron & Steel	88	3.5114	
	Pharma	92	3.4130	
	Oil/Gas	96	3.4792	
	Chemical	72	3.4306	
	Electronics & Electrics	101	3.5842	
	Other Industries	108	3.5833	
	Total	733	3.5198	
LSS11	Food	87	3.5517	.068
	Automotive & spare parts	89	3.6404	
	Iron & Steel	88	3.6136	
	Pharma	92	3.5543	
	Oil/Gas	96	3.5000	
	Chemical	72	3.5000	
	Electronics & Electrics	101	3.4950	
	Other Industries	108	3.7593	
	Total	733	3.5812	
LSS12	Food	87	3.4023	.614
	Automotive & spare parts	89	3.4944	
	Iron & Steel	88	3.4432	
	Pharma	92	3.4239	
	Oil/Gas	96	3.3542	
	Chemical	72	3.3750	
	Electronics & Electrics	101	3.3762	
	Other Industries	108	3.5000	
	Total	733	3.4229	
LSS13	Food	87	3.5287	.210
	Automotive & spare parts	89	3.6742	
	Iron & Steel	88	3.5341	
	Pharma	92	3.4457	
	Oil/Gas	96	3.4792	
	Chemical	72	3.4583	
	Electronics & Electrics	101	3.5050	
	Other Industries	108	3.6296	
	Total	733	3.5348	
LSS14	Food	87	3.5862	.690
	Automotive & spare parts	89	3.6854	
	Iron & Steel	88	3.5682	
	Pharma	92	3.5000	
	Oil/Gas	96	3.5313	
	Chemical	72	3.5000	
	Electronics & Electrics	101	3.5941	
	Other Industries	108	3.6481	
	Total	733	3.5798	
LSS15	Food	87	3.5057	.784
	Automotive & spare parts	89	3.5506	
	Iron & Steel	88	3.5000	
	Pharma	92	3.5326	
	Oil/Gas	96	3.4792	
	Chemical	72	3.4722	
	Electronics & Electrics	101	3.4554	
	Other Industries	108	3.6111	
	Total	733	3.5157	
LSS16	Food	87	3.8736	.435
	Automotive & spare parts	89	3.8539	
	Iron & Steel	88	3.7159	
	Pharma	92	3.8370	
	Oil/Gas	96	3.7188	
	Chemical	72	3.8611	
	Electronics & Electrics	101	3.9010	
	Other Industries	108	3.8981	
	Total	733	3.8336	

(Continued)

(Continued)

Table 9. Continued.

Variables	Sector	N	Mean	P-value
LSS17	Food	87	3.9770	.760
	Automotive & spare parts	89	3.9663	
	Iron & Steel	88	3.8523	
	Pharma	92	3.7935	
	Oil/Gas	96	3.8333	
	Chemical	72	3.8472	
	Electronics & Electrics	101	3.9010	
	Other Industries	108	3.8704	
	Total	733	3.8799	
LSS18	Food	87	3.9195	.685
	Automotive & spare parts	89	4.0000	
	Iron & Steel	88	3.8295	
	Pharma	92	3.8370	
	Oil/Gas	96	3.8229	
	Chemical	72	3.8056	
	Electronics & Electrics	101	3.7921	
	Other Industries	108	3.8611	
	Total	733	3.8581	
CSF1	Food	87	4.0230	.638
	Automotive & spare parts	89	4.0449	
	Iron & Steel	88	3.9091	
	Pharma	92	3.8913	
	Oil/Gas	96	3.9167	
	Chemical	72	3.9306	
	Electronics & Electrics	101	3.9406	
	Other Industries	108	4.0741	
	Total	733	3.9686	
CSF2	Food	87	4.1724	.356
	Automotive & spare parts	89	4.1461	
	Iron & Steel	88	4.0795	
	Pharma	92	4.0109	
	Oil/Gas	96	4.0729	
	Chemical	72	4.1111	
	Electronics & Electrics	101	4.0990	
	Other Industries	108	4.2685	
	Total	733	4.1228	
CSF3	Food	87	3.9540	.342
	Automotive & spare parts	89	4.0674	
	Iron & Steel	88	3.8750	
	Pharma	92	3.8478	
	Oil/Gas	96	3.9271	
	Chemical	72	3.8611	
	Electronics & Electrics	101	3.8614	
	Other Industries	108	4.0370	
	Total	733	3.9318	
CSF4	Food	87	4.1149	.509
	Automotive & spare parts	89	4.1348	
	Iron & Steel	88	4.0455	
	Pharma	92	4.0543	
	Oil/Gas	96	4.0417	
	Chemical	72	4.0000	
	Electronics & Electrics	101	4.0792	
	Other Industries	108	4.2222	
	Total	733	4.0914	
CSF5	Food	87	4.1034	.216
	Automotive & spare parts	89	4.1236	
	Iron & Steel	88	3.9545	
	Pharma	92	4.0435	
	Oil/Gas	96	3.9792	
	Chemical	72	4.0556	
	Electronics & Electrics	101	4.0891	
	Other Industries	108	4.1389	
	Total	733	4.0628	
CSF6	Food	87	3.8736	.541
	Automotive & spare parts	89	3.9663	
	Iron & Steel	88	3.7955	
	Pharma	92	3.7935	
	Oil/Gas	96	3.8750	
	Chemical	72	3.8194	
	Electronics & Electrics	101	3.7921	
	Other Industries	108	3.9352	
	Total	733	3.8581	

(Continued)

Table 9. Continued.

Variables	Sector	N	Mean	P-value
CSF7	Food	87	3.9540	.692
	Automotive & spare parts	89	4.0225	
	Iron & Steel	88	3.9545	
	Pharma	92	3.9348	
	Oil/Gas	96	4.0313	
	Chemical	72	3.8750	
	Electronics & Electrics	101	3.9307	
	Other Industries	108	4.0370	
	Total	733	3.9714	
CSF8	Food	87	3.9425	.283
	Automotive & spare parts	89	4.0112	
	Iron & Steel	88	3.8750	
	Pharma	92	3.8804	
	Oil/Gas	96	3.8125	
	Chemical	72	3.9167	
	Electronics & Electrics	101	3.9109	
	Other Industries	108	4.0000	
	Total	733	3.9195	
CSF9	Food	87	4.0575	.713
	Automotive & spare parts	89	4.0787	
	Iron & Steel	88	4.0114	
	Pharma	92	3.9674	
	Oil/Gas	96	3.9792	
	Chemical	72	3.9306	
	Electronics & Electrics	101	3.9703	
	Other Industries	108	4.1111	
	Total	733	4.0164	
CSF10	Food	87	4.0000	.634
	Automotive & spare parts	89	4.0112	
	Iron & Steel	88	3.9545	
	Pharma	92	3.8696	
	Oil/Gas	96	3.9063	
	Chemical	72	3.9028	
	Electronics & Electrics	101	3.9406	
	Other Industries	108	4.0463	
	Total	733	3.9563	

implementation, and I4.0 CSF of Implementation, as the corresponding P-values are more than 0.05.

Discussion and conclusion

In this research, the critical success factors for LSS had been explored and a total of 18 factors had been observed. Also, 10 critical success factors for I4.0 had been explored. Then, by examining the effect of LSS critical success factors on I4.0 implementation, it was observed that there are main LSS factors when considering the I4.0 implementation.

For example, when examining the effect of LSS factors on the first industry 4.0 factor; digitize the organization, it was found that LSS critical success factors significantly affects I4.0:1 with a percentage of 79.1%. This effect is due to the LSS listed factors in order as follows: (1) LSS18 - Considering the final result or outcome, (2) LSS17 - Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets, (3) LSS11 - The organization demonstrates the need for change, (4) LSS16 - Explaining activities and releasing the results in a transparent manner (5) LSS13 -

communication between an organization and its employees, (6) LSS4 - Leadership has vision and is capable of leading, (7) LSS6 - Organizational culture fit with Lean Six Sigma implementation, (8) LSS15 - Providing information technology support, (9) LSS5 - Organizational procedures and policies based on defined responsibilities and duties of its employees, (10) LSS3 - Top management support, (11) LSS9 - Employees committed to the organization, (12) LSS12 - Work activities are organized around teams rather than individuals.

Also, when examining the effect of LSS factors on the second industry 4.0 factor; change management, it was found that LSS critical success factors significantly affects I4.0:2 with a percentage of 71.8%. This effect is due to the LSS listed factors in order as follows: (1) LSS17 - Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets, (2) LSS18 - Considering the final result or outcome, (3) LSS16 - Explaining activities and releasing the results in a transparent manner, (4) LSS11 - The organization demonstrates the need for change, (5) LSS5 - Organizational procedures and policies based on defined responsibilities and duties of its employees, (6) LSS6 - Organizational culture fit with Lean Six Sigma implementation, (7) LSS13 - Commitment and communication between an organization and its employees, (8) LSS12 - Work activities are organized around teams rather than individuals, (9) LSS15 - Providing information technology support.

In addition, when examining the effect of LSS factors on the third industry 4.0 factor; managing cyber security, it was found that LSS critical success factors significantly affects I4.0:3 with a percentage of 52.4%. This effect is due to the LSS listed factors in order as follows: (1) LSS18 - Considering the final result or outcome, (2) LSS11 - The organization demonstrates the need for change, (3) LSS14 - Providing Training to employees, (4) LSS16 - Explaining activities and releasing the results in a transparent manner, (5) LSS17 - Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets, (6) LSS15 - Providing information technology support, (7) LSS13 - Commitment and communication between an organization and its employees, (8) LSS9 - Employees committed to the organization, (9) LSS4 - Leadership has vision and is capable of leading.

Moreover, when examining the effect of LSS factors on the fourth industry 4.0 factor; importance of Employees, it was found that LSS critical success factors significantly affects I4.0:4 with a percentage of 69.7%. This effect is due to the LSS listed factors in order as follows: (1) LSS17 - Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets, (2) LSS18 - Considering the final result or outcome, (3) LSS16 - Explaining activities and releasing the results in a transparent manner, (4) LSS11 - The organization demonstrates the need for change, (5) LSS6 - Organizational culture fit with Lean Six Sigma implementation, (6) LSS4 - Leadership has vision and is capable of leading, (7) LSS13 - Commitment and communication between an organization and its employees, (8) LSS3 - Top management support, (9) LSS15 - Providing information technology support, (10) LSS9 - Employees committed to the organization, (11) LSS5 - Organizational procedures and policies based on defined responsibilities and duties of its employees.

Furthermore, when examining the effect of LSS factors on the fifth industry 4.0 factor; top management support, it was found that LSS critical success factors significantly affects I4.0:5 with a percentage of 41.9%. This effect is due to the LSS listed factors in order as follows: (1) LSS18 - Considering the final result or outcome, (2) LSS17 - Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets, (3) LSS3 - Top management support, (4) LSS11 - The organization demonstrates the need for change, (5) LSS13 - Commitment and communication between an organization and its employees, (6) LSS16 - Explaining activities and releasing the results in a transparent manner.

Besides, when examining the effect of LSS factors on the sixth I4.0 factor; align the organizational strategy with the I4.0 efforts, it was found that LSS critical success factors significantly affects I4.0:6 with a percentage of 56.2%. This effect is due to the LSS listed factors in order as follows: (1) LSS11 - The organization demonstrates the need for change, (2) LSS16 - Explaining activities and releasing the results in a transparent manner, (3) LSS13 - Commitment and communication between an organization and its employees, (4) LSS15 - Providing information technology support, (5) LSS18 - Considering the final result or outcome, (6) LSS17 - Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets, (7) LSS14 - Providing Training to employees, (8) LSS6 - Organizational culture fit with Lean Six Sigma implementation.

Also, when examining the effect of LSS factors on the seventh industry 4.0 factor; digitize the supply chain, it was found that LSS critical success factors

significantly affects I4.0:7 with a percentage of 41.5%. This effect is due to the LSS listed factors in order as follows: (1) LSS18 - Considering the final result or outcome, (2) LSS11 - The organization demonstrates the need for change, (3) LSS13 - Commitment and communication between an organization and its employees, (4) LSS15 - Providing information technology support, (5) LSS17 - Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets, (6) LSS2 - Focusing on business (customer) results, (7) LSS16 - Explaining activities and releasing the results in a transparent manner, (8) LSS14 - Providing Training to employees.

In addition, when examining the effect of LSS factors on the eighth industry 4.0 factor; project management, it was found that LSS critical success factors significantly affects I4.0:8 with a percentage of 46.9%. This effect is due to the LSS listed factors in order as follows: (1) LSS18 - Considering the final result or outcome, (2) LSS17 - Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets, (3) LSS11 - The organization demonstrates the need for change, (4) LSS13 - Commitment and communication between an organization and its employees, (5) LSS6 - Organizational culture fit with Lean Six Sigma implementation, (6) LSS:9 - Employees committed to the organization, (7) LSS16 - Explaining activities and releasing the results in a transparent manner.

Furthermore, when examining the effect of LSS factors on the ninth industry 4.0 factor; make your goods and services intelligent, it was found that LSS critical success factors significantly affects I4.0:9 with a percentage of 49.2%. This effect is due to the LSS listed factors in order as follows: (1) LSS11 - The organization demonstrates the need for change, (2) LSS18 - Considering the final result or outcome, (3) LSS13 - Commitment and communication between an organization and its employees, (4) LSS12 - Work activities are organized around teams rather than individuals, (5) LSS15 - Providing information technology support, (6) LSS14 - Providing Training to employees, (7) LSS16 - Explaining activities and releasing the results in a transparent manner, (8) LSS4 - Leadership has vision and is capable of leading.

Furthermore, when examining the effect of LSS factors on the tenth I4.0 factor; the future of work and sustainability, it was found that LSS critical success factors significantly affects I4.0:10 with a percentage of 59.1%. This effect is due to the LSS listed factors in order as follows: (1) LSS18 - Considering the final result or outcome, (2) LSS11 - The organization demonstrates the need for change, (3) LSS17 - Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets, (4) LSS13 - Commitment and communication between an organization and its employees, (5) LSS4 - Leadership has vision and is capable of leading, (6) LSS16 – Explaining activities and releasing the results in a transparent manner, (7) LSS12 – Work activities are organized around teams rather than individuals, (8) LSS15 - Providing information technology support.

Finally, these results agree with many researchers like (Bhat, Bhat, and Gijo 2021; Aguayo et al. 2022; Sordan et al. 2022).

For the theoretical contribution, there are few researches that address how I4.0 and LSS might be combined. Therefore, this research offered CSF of LSS that could be considered important for I4.0 implementation within Egyptian Manufacturing Sector; such as utilization of the necessary procedures, techniques, knowledge, abilities, and experience to accomplish the project's goals, employees committed to the organization, the organization gives rewards and appreciation to employees for meeting a pre-determined goal, explaining activities and releasing the results in a transparent manner, monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets.

For the practical contribution, the research was conducted with input from industry practitioners, so the results are of practical relevance that will help manufacturing industry be well prepared for the CSF of LSS that could be considered important for I4.0 implementation within Egyptian Manufacturing Sector.

Table 10 illustrates the factors of critical success factors of LSS affecting I4.0 implementation. It could be observed that the dominant LSS factors in I4.0 implementation are LSS11 - The organization demonstrates the need for change, LSS12 - Work activities are organized around teams rather than individuals, LSS13 - Commitment and communication between an organization and its employees, LSS15 - Providing information technology support, LSS16 - Explaining activities and releasing the results in a transparent manner, LSS17 - Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets, and LSS18 - Considering the final result or outcome. This means that the mentioned factors are the important ones for achieving I4.0 and managers should consider such factors when thinking strategically regarding I4.0 implementation in general.

Table 10. Integration of LSS and I4.0 implementation.

P	CSF	LSS	Description
1	Digitize the organization	LSS3 LSS4 LSS5 LSS6 LSS9 LSS11 LSS12 LSS13 LSS15 LSS17 LSS18	(1) LSS18 - Considering the final result or outcome, (2) LSS17 - Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets, (3) LSS11 - The organization demonstrates the need for change, (4) LSS16 - Explaining activities and releasing the results in a transparent manner, (5) LSS13 - Commitment and communication between an organization and its employees, (6) LSS4 - Leadership has vision and is capable of leading, (7) LSS6 - Organizational culture fit with Lean Six Sigma implementation, (8) LSS15 - Providing information technology support, (9) LSS5 - Organizational procedures and policies based on defined responsibilities and duties of its employees, (10) LSS3 - Top management support, (11) LSS9 - Employees committed to the organization, (12) LSS12 - Work activities are organized around teams rather than individuals
2	change management	LSS5 LSS6 LSS11 LSS12 LSS13 LSS15 LSS16 LSS17 LSS18	(1) LSS17 - Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets, (2) LSS18 - Considering the final result or outcome, (3) LSS16 - Explaining activities and releasing the results in a transparent manner, (4) LSS11 - The organization demonstrates the need for change, (5) LSS5 - Organizational procedures and policies based on defined responsibilities and duties of its employees, (6) LSS6 - Organizational culture fit with Lean Six Sigma implementation, (7) LSS13 - Commitment and communication between an organization and its employees, (8) LSS12 - Work activities are organized around teams rather than individuals, (9) LSS15 - Providing information technology support
3	managing cyber security	LSS4 LSS9 LSS11 LSS13 LSS14 LSS15 LSS16 LSS17 LSS18	(1) LSS18 - Considering the final result or outcome, (2) LSS11 - The organization demonstrates the need for change, (3) LSS14 - Providing Training to employees, (4) LSS16 - Explaining activities and releasing the results in a transparent manner, (5) LSS17 - Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets, (6) LSS15 - Providing information technology support, (7) LSS13 - Commitment and communication between an organization and its employees, (8) LSS9 - Employees committed to the organization, (9) LSS4 - Leadership has vision and is capable of leading
4	importance of Employees	LSS3 LSS4 LSS5 LSS6 LSS9 LSS11 LSS13 LSS15 LSS16 LSS17 LSS18	(1) LSS17 - Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets, (2) LSS18 - Considering the final result or outcome, (3) LSS16 - Explaining activities and releasing the results in a transparent manner, (4) LSS11 - The organization demonstrates the need for change, (5) LSS6 - Organizational culture fit with Lean Six Sigma implementation, (6) LSS4 - Leadership has vision and is capable of leading, (7) LSS13 - Commitment and communication between an organization and its employees, (8) LSS3 - Top management support, (9) LSS15 - Providing information technology support, (10) LSS9 - Employees committed to the organization, (11) LSS5 - Organizational procedures and policies based on defined responsibilities and duties of its employees
5	top management support	LSS3 LSS11 LSS13 LSS16 LSS17 LSS18	(1) LSS18 - Considering the final result or outcome, (2) LSS17 - Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets, (3) LSS3 - Top management support, (4) LSS11 - The organization demonstrates the need for change, (5) LSS13 - Commitment and communication between an organization and its employees, (6) LSS16 - Explaining activities and releasing the results in a transparent manner
6	align the organizational strategy with the I4.0 efforts	LSS6 LSS11 LSS13 LSS14 LSS15 LSS16 LSS17 LSS18	(1) LSS11 - The organization demonstrates the need for change, (2) LSS16 - Explaining activities and releasing the results in a transparent manner, (3) LSS13 - Commitment and communication between an organization and its employees, (4) LSS15 - Providing information technology support, (5) LSS18 - Considering the final result or outcome, (6) LSS17 - Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets, (7) LSS14 - Providing Training to employees, (8) LSS6 - Organizational culture fit with Lean Six Sigma implementation
7	digitize the supply chain	LSS2 LSS11 LSS13 LSS14 LSS15 LSS16 LSS17 LSS18	(1) LSS18 - Considering the final result or outcome, (2) LSS11 - The organization demonstrates the need for change, (3) LSS13 - Commitment and communication between an organization and its employees, (4) LSS15 - Providing information technology support, (5) LSS17 - Monitoring ongoing operations to make that the business is on schedule for achieving its goals and performance targets, (6) LSS2 - Focusing on business (customer) results, (7) LSS16 - Explaining activities and releasing the results in a transparent manner, (8) LSS14 - Providing Training to employees

(*Continued*)