THE CRITICAL SUCCESS FACTORS FOR LEAN SIX SIGMA IMPLEMENTATION IN SMALL-AND-MEDIUM-SIZED ENTERPRISES

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ABSTRACT

Lean six sigma (LSS) is an important business strategy for organisations, including small and medium-sized enterprises (SMEs). Over the years, SMEs have had a potentially significant impact on various countries' gross domestic product (GDP). The main purpose of this research is to investigate the critical success factors (CSFs) for lean six sigma (LSS) implementation in the Kingdom of Saudi Arabia's SMEs, and to contribute to discovering the factors that lead to business success, increase revenue, and enhanced competitive advantages. The study identified 29 factors from previous research in order to guide the successful implementation of LSS in the SME sector in Saudi Arabia in particular. The CSFs were refined, producing a consolidated list of 14 factors. A principal components analysis (PCA) identified four main factors: leadership support and management structure, technological capabilities, knowledge acquisition, and creativity and innovation. These factors could influence the success of SMEs in Saudi Arabia by adopting LSS in their business processes.

OPSOMMING

Lean six sigma (LSS) is 'n belangrike besigheidstrategie vir organisasies, insluitend klein en mediumgrootte ondernemings (KMO's). Oor die jare het KMO's 'n potensieel beduidende impak op verskeie lande se bruto binnelandse produk (BBP) gehad. Die hoofdoel van hierdie navorsing is om die kritieke suksesfaktore (CSF's) vir lean six sigma (LSS) implementering in die Koninkryk van Saoedi-Arabië se KMO's te ondersoek, en om by te dra tot die ontdekking van die faktore wat lei tot besigheidsukses, verhoogde inkomste en verbeterde mededingende voordele. Die studie het 29 faktore uit vorige navorsing geïdentifiseer ten einde die suksesvolle implementering van LSS in die KMO-sektor in veral Saoedi-Arabië te lei. Die CSF's is verfyn, wat 'n gekonsolideerde lys van 14 faktore opgelewer het. 'n Hoofkomponent-analise (PCA) het vier hooffaktore geïdentifiseer: leierskapondersteuning en bestuurstruktuur, tegnologiese vermoëns, kennisverkryging, en kreatiwiteit en innovasie. Hierdie faktore kan die sukses van KMO's in Saoedi-Arabië beïnvloed deur LSS in hul besigheidsprosesse aan te neem.

1. INTRODUCTION

Lean six sigma (LSS) has been widely used by numerous organisations worldwide as a continuous improvement method for cost reduction, process enhancement, and value creation for customers. According to [1], quality improvement and operational excellence can be achieved by using LSS. Leading companies in different countries, such as General Electric (GE) and Motorola, have reported several notable successes in LSS implementation. This results in reduced quality cost, improved process efficiency, satisfied customers, reduced defects and waste, increased revenue and market share, and continuous improvement strategies [2,3,4,5,6].

Since LSS is affected by Industry 4.0, it can generate huge benefits in improving business performance and achieving a competitive advantage [7]. Small and medium-sized enterprises (SMEs) are given much attention by different countries' governments as leading innovation and competition, increasing the rate of employment, and achieving long-term gains [8],[9]. This is owing to the potential impact of SMEs on a country's gross domestic product (GDP). Many studies have illustrated the potential value of SMEs in supporting the economic growth of a country through entrepreneurship and innovation, and by providing job opportunities.

In the Kingdom of Saudi Arabia (KSA) in particular, SMEs play an important role in economic development, and they contribute significantly to increasing employment opportunities [10]. The government has announced the Saudi Vision 2030, which includes several strategic plans to reduce economic dependence on oil and to utilise the available resources with multiple objectives. These objectives include transforming the SMEs sector into a basic engine for economic growth, increasing the SMEs' current contribution to GDP from 20 per cent to 35 per cent, and providing about 70 per cent of jobs in the private sector [11].

The exact nature of lean six sigma in Saudi Arabia is still evolving, as companies are still learning how best to implement these methodologies in their own culture and context.

Indeed, there is no single definitive answer to the question of what qualifies a company to be referred to as an LSS company. However, some common characteristics of LSS companies are a commitment to continuous improvement, a focus on data-driven decision-making, a strong emphasis on employee engagement, creativity and innovation, and a track record of success in implementing LSS projects.

There is a growing interest in lean six sigma among SMEs in Saudi Arabia. However, there is still a lack of understanding of what it means to be an LSS company. Some SMEs may believe that they need to have a full LSS programme in place in order to be considered an LSS company [12].

SMEs in Saudi Arabia could still benefit from LSS principles and techniques, even if they did not have a formal LSS programme in place. The authors believe that SMEs could implement LSS through training employees on LSS tools and techniques, using the Kaizen methodogy to identify and eliminate waste, implementing six sigma projects to improve specific processes, measuring and tracking performance metrics, and creating a culture of continuous improvement. If a company exhibits these qualities, then it can be considered an LSS company.

According to the KSA's General Authority for Statistics [10], the number of SMEs in the Makkah Region (Western Region) by the end of 2021 accounted for about 27 per cent of the total number of SMEs in the KSA. Indeed, little research has been conducted on LSS implementation in SMEs [13]. Previous research has explained that few publications are available on LSS implementation in the manufacturing and non-manufacturing sectors [14]. Not many studies have been conducted on the critical success factors (CSFs) for LSS implementation [15]. Furthermore, few researchers have addressed the use of LSS in SMEs [16]. Thus this research aimed to identify the CSFs for a successful implementation of LSS in Saudi SMEs.

The study has been organised systematically. First, LSS, SMEs, and CSFs are introduced and described. Second, a review of CSF for LSS implementation in SMEs is presented. Third, the research methodology and the details of the questionnaire, along with some analytical tools used in this research, are explained. Fourth, the research findings focus on the underlying description of the identified factors. The last section provides a conclusion and directions for future research.

1.1. Lean six sigma

Lean six sigma (LSS) is a method of quality improvement by integrating lean manufacturing and six sigma (SS). It relies on removing waste, improving performance, and achieving zero defects by identifying value-added and non-value-added activities in the workplace. According to [13], LSS is a methodological tool that plays a significant role in improving quality and services, increasing customer satisfaction, and reducing costs. It can be achieved by implementing the tools and principles of lean and six sigma. The term 'lean' focuses on eliminating several types of waste (Muda), whereas SS focuses on improving the quality of the process by identifying the causes of defects, thus leading to reduced variability in the process. By implementing LSS, organisations can identify and reduce waste and save money [16]. According to [1], the implementation of LSS in SMEs has several benefits, including reducing non-value-added activities and lead times, achieving on-time delivery, and saving money.

1.2. Small and medium-sized enterprises

Small and medium-sized enterprises (SMEs) make a major contribution to modern economies by creating job opportunities, improving productivity, increasing income, and boosting innovation [17,18]. SMEs can be categorised into various groups according to the number of employees, annual revenue, and business assets [19]. Several countries use different classifications to define the term 'small business'. For instance, a small business enterprise in the United States has 500 employees or fewer, whereas in European countries a business enterprise is classified as 'small' if it has fewer than 50 employees. The KSA describes a small business as having three to 49 employees and a total annual revenue of around US$1.3 million or less.

1.3. Quality and customer satisfaction

Quality pioneers have developed quality management practices to improve quality and achieve customer satisfaction. Indeed, using quality tools, concepts, and techniques is important for satisfying customer needs. This is because of the increased level of competition in the business environment. Edwards and Deming [20] focused on management's responsibility for building a good quality system, and proposed 14 points in implementing quality improvement. Juran [21] strongly emphasised the top management's commitment and support in promoting the concept of quality to employees. Feigenbaum [22] viewed quality as total quality management (TQM) that involves everyone in the organisation. Crosby [23] stated that there was a traditional trade-off between the cost of improving quality and the cost of poor quality, and he promoted the 'zero defects' concept.

1.4. Critical success factors

'Critical success factors' (CSFs) is a term used to identify the key factors that are required to ensure the success of an organisation and to achieve a competitive advantage. [24] defined CSF as several elements that should be considered to achieve organisational objectives. The factors should be constantly evaluated against competitors to ensure an SME's success. However, there is no collective agreement among researchers on a specific set of factors that could influence the success of SMEs [25].

1.5. Importance of the study in the Kingdom of Saudi Arabia context

Enterprises in the KSA face several difficulties as a result of globalisation and increased numbers of foreign products from multiple countries in local markets. Moreover, there is a high level of demand from customers to buy products of better quality, a fast mode of delivery, and reasonable prices. Thus entrepreneurs seek to respond to customers' requirements and to give satisfaction by using advanced technology or tools such as mobile applications, internet-based tools, and integrated database-based technologies [12]. Saudi Arabia has been concerned about expanding the role of SMEs in its economy. In 2020, the government offered small enterprises financial support of around SR50 billion to overcome the crisis of COVID-19. This action was taken to attain the goal of Saudi Vision 2030, which includes increasing SMEs' contribution to GDP from 20 per cent to 35 per cent and raising the private sector's contribution from 40 per cent to 65 per cent. The KSA used the following characteristics of enterprises [26]:

Table 1: Enterprises' characteristics in the Kingdom of Saudi Arabia

Micro	Small	Medium
1 – 5 employees	6 – 49 employees	50 – 249 employees
0 – SR3 million	Over SR3 million – SR40 million	Over SR40 million – SR200 million

[27] stated that the main CSFs of SMEs in Saudi Arabia are their business characteristics, the business environment, their management factors, their individual factors, business support, and capital investment. These factors led the authors of this study to use quality improvement techniques such as LSS.

1.6. Lean implementation in small and medium-sized enterprises

The main objective of lean implementation in SMEs is to reduce waste and to optimise operational processes [28],[29]. A literature research showed that the success of lean implementation in SMEs depends on several sets of factors. For instance, Moeuf *et al.* [28] identified three CSFs of lean in SMEs: leadership, experience, and decision-making power. Nguyen [30] identified the following CSFs for lean implementation in SMEs: management's involvement and direction; employee engagement; culture change; resource allocation; training; coaching and consulting; teaching; and measuring key performance indicators. Singh and Jain [31] studied the CSFs in British manufacturing SMEs, and listed the following: management's involvement and commitment; communication; cultural change; and education and training. Alefari *et al.* [32] explored the success factors affecting United Arab Emirates (UAE) SMEs' performance in the manufacturing sector, and identified financial motivations; leadership; managerial support; teamwork; recognition; and training.

Arabi *et al.* [33] explained the success factors in implementing lean and in promoting change in and the development of SMEs. These were the involvement and commitment of the top management; the involvement and participation of employees; the ability and willingness to change the organisational structure; training the employees; communicating goals and objectives; and developing employees' skills.

1.7. Lean six sigma in small and medium-sized enterprises

LSS in SMEs combines the principles of lean with the tools and techniques of six sigma. This provides a more comprehensive and powerful approach to improvement than conventional lean. LSS can help SMEs to improve their work efficiency, productivity, and quality in a way that is sustainable over time. In addition, LSS provides a clear roadmap for improvement that could help SMEs to avoid costly mistakes [16].

In fact, LSS uses a broader range of tools and techniques in incorporating the tools and techniques of lean and the statistical tools of six sigma. This gives SMEs a more powerful set of tools for their improvement efforts. LSS is a more complex approach to improvement than conventional lean, and it requires a stronger commitment from leaders to be successful.

The literature reveals that several factors lead to the successful implementation of LSS in SMEs. A list of published papers related to the implementation of LSS in SMEs is given in Table 2. Previous research showed that there were limited studies of using LSS in SMEs in developing countries, including the KSA. Thus the objective of this study was to identify the critical success factors for LSS implementation in Saudi Arabian SMEs.

Table 2: CSFs for LSS implementation in SMEs

Authors	Year	Country	CSFs
[34]	2003	Malaysia	Visible management commitment; clear definition of customers' requirements; shared understanding of core business processes and their critical characteristics; rewarding and recognising team members; communicating the success and failure stories; selecting the right people and the right projects.
[35]	2005	The United Kingdom (UK)	Management involvement and participation; organisational infrastructure; cultural change; training; linking six sigma to business strategy; linking six sigma to employees; linking six sigma to customers; linking six sigma to suppliers; understanding of six sigma methodologies; project management skills; project prioritisation and selection.
[36]	2006	UK	Leadership and management; finance; skills and expertise; organisational culture.

Authors	Year	Country	CSFs
[37]	2007	UK	Management involvement; organisational infrastructure; cultural change; education and training; vision and plan statement; linking six sigma to customers; linking six sigma to business strategy; linking six sigma to employees; linking six sigma to suppliers; communication; understanding of six sigma; project management skills; project prioritisation and selection.
[38]	2008	Thailand	A pattern of full-time or part-time black belt; belts' reporting structure to project champion; inclusion of a dedicated team for technical support; effective six sigma training programmes; the nature of management involvement.
[39]	2011	Norway and Belgium	Leadership and management involvement; employee involvement and sufficient participation; change in the organisational culture and the time factor; motivation and learning; performance evaluation systems; communication of goals and objectives with improvement initiatives; linking improvement initiatives to business strategy and customers.
[40]	2011	Italy	Management involvement and commitment; cultural change; communication; organisational infrastructure and culture; education and training; linking six sigma to business strategy; linking six sigma to the customer; linking six sigma to human resources; linking six sigma to suppliers; understanding tools and techniques in six sigma; project management skills; project prioritisation and selection.
[41]	2012	India	Enhanced facilities and layout configuration; skilled resources/ capability of workers; stability in production schedule; strong relationships with suppliers and customers.
[42]	2012	The United States (US)	Leadership and involvement of management; company's long-term vision; time allocation and financial resources; availability of expertise and know-how; culture change; employees' empowerment; using measurement system.
[43]	2012	The Netherlands	The highest-ranked CSFs: linking to the customer; vision and plan statement; communication; management involvement and participation. The strongest impeding factors: internal resistance; the non-availability of resources; changing business focus and lack of leadership.
[44]	2013	Malaysia	Leadership; structured improvement procedure; quality information and analysis; supplier relationships; use of just-in-time; customer focus; focus on metrics; teamwork; congenial inter-personal relations; delegation and empowerment; process improvement.
[45]	2014	Finland	Long-term vision; efficient decision-making process; use of feasible lean tools and methods; contact with professional associates and outside consultants; strong relationships with suppliers and customers; empowerment of employees.
[46]	2014	UK	Financial resources; user training and education; monitoring and evaluating progress; project champion; trust between partners; user involvement and participation; top management support; effective communication; change the culture; clear goals and objectives.
[47]	2014	India	Leadership and management involvement; allocation of time and financial resources; culture change; formal training for workers; levelling product variety.

Authors	Year	Country	CSFs
[48]	2015	UK	Commitment of top management; culture; piecemeal approach; training; multifunctional team; resources; organisational structure; remuneration; change agent.
[49]	2016	India	Training (employee involvement); management involvement and commitment; customer satisfaction; leadership; project prioritisation and selection; cultural change; understanding LSS methodology; strategic quality planning; process management; product design; linking LSS to customers; linking LSS to business strategy; employee satisfaction; employee rewards; inventory control; communication of information; linking LSS to employees; linking LSS to suppliers; employee relations/empowerment; quality measurement system/quality data; benchmarking; role of quality department.
[50]	2016	Morocco	Management involvement and support; alignment with the global strategy of the company; long-term vision: training by lean expertise consultant; proper selection of lean parameters; proper planning before implementation; earlier culture change; improvement with small pilot projects; time and resource allocation; all employees' involvement; performance measurement; standardisation and capitalisation of best practices.
[51]	2017	India	Management support; relationships with suppliers and customers; tools and techniques; continuous improvement; process evaluation and monitoring; employee involvement, and rewards and recognition.
[52]	2017	India	Management involvement and leadership; customers' and suppliers' involvement; understanding of six sigma philosophy; resources utilisation and audits; functional teams and effective communication; employee involvement.
[14]	2018	UK	Project management; leadership; selection of top talented people; financial accountability.
[53]	2018	UK	Management involvement and commitment; communication; link quality initiatives to the employee; cultural change; education and training; link quality initiatives to customers' project selection; link quality initiatives to business; link quality initiatives to the supplier; project management skills; organisation infrastructure; vision and plan; IT and innovation.
[54]	2018	India	Knowledge and lean expertise; senior management commitment; organisational culture; quantified benefits; ways of working with resources; attitude of workers; internal resistance; disruption in operations; budget; clarity across functional groups; training; integration with business associates.
[16]	2019	Morocco	Policy, leadership, and management; funding, technic, and process; culture, humans, and competencies; market, customers, and suppliers; understanding, methodology, and implementation.
[55]	2022	Pakistan	Management participation and support; training and education; leadership for Green Lean and Six Sigma (GLSS); legislation; organisational infrastructure; understanding of GLSS methodologies; technology up-grading; linking GLSS to customers; communication plan/ system; linking GLSS to business strategy; linking GLSS to employees; project management skills; cultural change (awareness); linking GLSS to suppliers; societal influences; project prioritisation and selection.

2. RESEARCH METHODOLOGY

This section describes the steps involved in the research methodology.

First, a list of CSFs for LSS implementation in SMEs was identified, based on the extensive literature review. Second, two academics and two entrepreneurs related to SMEs in the KSA were invited to a focus group discussion to provide the most important CSFs that would apply to SMEs in the Saudi environment. Third, a survey questionnaire was designed that contained closed-ended questions. Quantitative data were measured by a five-point Likert scale, ranging from one to five – 'strongly agree' to 'strongly disagree' respectively. Fourth, the principal components analysis (PCA) method was used to discover the relationships among the factors. The last step was to identify the main CSFs for implementing LSS in Saudi SMEs.

3. RESULTS

3.1. List of CSFs for LSS implementation in SMEs

The review of the literature on LSS implementation in SMEs initially resulted in identifying 29 CSFs after excluding duplicate factors with similar meanings. The identified factors needed further investigation and evaluation to explore their importance in influencing the successful implementation of LSS in SMEs.

3.2. Focus-group discussion

The 29 CSFs were identified from a literature review. To validate the 29 CSFs, a survey was designed and administered to two academics and two entrepreneurs with good knowledge and work experience in LSS applications. The survey asked the participants to recommend the inclusion or exclusion of each CSF. A focus-group discussion was conducted, and a total of 13 CSFs were selected out of the 29 that had been first identified. The considered factors were consistent with the KSA SME context and expected to influence and contribute to the successful implantation of LSS in Saudi Arabian SMEs. As recommended by the participants, 'adoption of Quality 4.0 in the context of Industry 4.0' was an important factor that could help SMEs to compete with larger companies and to improve their overall performance. Thus this factor was added to the final list.

'Quality 4.0' refers to the integration of advanced technologies to improve efficiency, quality, and productivity in order to remain competitive in today's rapidly changing business environment. It can be adopted by SMEs by facilitating the implementation of digital transformation and development of their IT structure. Furthermore, the automation of lean leads to several benefits for SMEs in supplier support, greater customer satisfaction, improved process control systems, and the management of the human factors [56].

The final set of recommended factors was included in the questionnaire items, and is listed below:

1. Top management support and commitment
2. Advanced tools for communication and information flow
3. Teamwork and collaboration
4. Organisational culture and structure
5. Employees' development and engagement
6. Understanding customer requirements
7. Cooperative supplier relationships
8. Strategic quality planning
9. Linking LSS with customer satisfaction and business strategy
10. Adopting a recognition and reward system
11. Managers' and employees' awareness of LSS tools and techniques
12. Project management skills
13. Prioritise business quality
14. Adoption of Quality 4.0 within Industry 4.0.

3.3. Survey questionnaire

The study undertook a survey of 104 SMEs located in Jeddah City (in the Western Region of the KSA). A self-administered questionnaire was developed, based on an extensive review of the literature related to the CSFs for LSS implementation in SMEs. The study targeted the managers and owners of SMEs. All of the respondents provided written informed consent prior to participating in the study. The enterprise business types covered in this study were the wholesale and retail trade, accommodation and food services, and education services.

The online questionnaire included a short introduction and the overall purpose of the study. It had two parts, and was provided in both English and Arabic. The first part sought the demographic characteristics of the respondents, such as gender, age, educational level, number of employees, and business type (Table 3).

Table 3: Demographic information

Profile	N	%
Gender		
Male	39	63.9%
Female	22	36.1%
Age		
25–35	17	27.9%
36–45	34	55.7%
46–55	7	11.5%
Over 55	3	4.92%
Education		
High school	9	14.8%
Diploma	6	9.80%
Bachelor's degree	36	59.0%
Master's or PhD	10	16.4%
Employees		
1–5	11	18.0%
6–49	41	67.2%
50–249	9	14.8%
Business type		
Wholesale and retail trade	22	36.1%
Accommodation and food services	34	55.7%
Education service	5	8.20%

3.4. Sample

Of the 104 questionnaires that were distributed, 61 were received after their completion (a response rate of 59 per cent). The results showed that the majority of the participants (63.9 per cent) were males, while 36.1 per cent were females. In respect of the entrepreneurs' age, the majority of the participants (55.7 per cent) were between 36 and 45 years; the rest were between 25 and 35 years (27.9 per cent) or between

46 and 55 years (11.5 per cent); only 4.92 per cent were over the age of 55. This indicated that the SMEs depended mainly on young people.

The participants' educational level indicated that some of them were educated at the high school level (14.8 per cent), and some held a diploma (9.80 per cent). However, the majority of them were bachelor's degree holders (59 per cent) and Master's or PhD graduates (16.4 per cent).

The survey data revealed that 18 per cent of the SMEs had one to five employees, 67.2 per cent had six to 49 employees, and 14.8 per cent or the enterprises had 50 to 249 employees. The business types of the SMEs showed that 36.1 per cent of them were in the wholesale and retail trade, 55.7 per cent were related to accommodation and food services, and only 8.2 per cent were in education services.

The second part of the questionnaire contained closed-ended questions. A total of 56 items were developed, based on the factors selected and recommended by the focus group members (Table 4).

Table 4: Questionnaire items

Factor	Items
Leadership support and management structure	1.1 Top management support of LSS implementation 1.2 Leaders spread out the concepts of LSS to the employees 1.3 Managers pursue new targets and new strategies related to LSS 1.4 Leaders paid sufficient attention to the business strategy
Advanced tools for communication and information flow	2.1 Dissemination of the concept of waste reduction and the presence of information systems 2.2 Focus on the elimination of waste in the production chain 2.3 Utilization of pull production 2.4 Mechanisms of reducing process variability
Teamwork and collaboration	3.1 Encourage staff to solve practice problems effectively 3.2 Involve managers in common goals 3.3 Empower employees to make decisions and take action 3.4 Keep employees' ideas always valued
Organisational culture and structure	4.1 Spreading the culture of LSS concepts 4.2 Dissemination of the culture of continuous improvement 4.3 Allocate resources for cultural adaptation 4.4 Using a structured approach to manage quality improvement activities.
Employees' development and engagement	5.1. Provide training programs for leaders 5.2. Provide training programs and education for employees 5.3. Offer motivation programs for leaders 5.4 Engage employees in continuous improvement activities
Understanding customers' requirements	6.1 Products and services based on customer requirements 6.2 Conduct a regular customer satisfaction survey 6.3 Study the current market and respond to customer needs 6.4 Involve the customer in future products
Cooperative supplier relationships	7.1 Apply corporate-level communication with suppliers 7.2 Involve suppliers in waste and cost reduction strategies 7.3 Solve quality problems with suppliers using LSS tools 7.4 Encourage suppliers to develop advanced production capabilities

Factor	Items
Strategic quality planning	8.1 Use of LSS tools in the process to reduce variability
	8.2 Use of LSS tools in the process to minimize waste
	8.3 Apply for quality programs in all business activities
	8.4 Conduct a systematic approach to quality assurance and improvement plans
Linking LSS with customer satisfaction and business strategy	9.1 Utilize LSS tools to solve customer complaints
	9.2 Develop business strategies based on LSS concepts
	9.3 Use LSS as a strategic approach to improve business profitability and achieve operational excellence
	9.4 Use LSS to manage quality improvement activities
Adopting a recognition and reward system	10.1 Provide recognition and awards to employees who participated in continuous improvement programs
	10.2 Acknowledged employees for their performance in intrinsic or extrinsic ways
	10.3 Existence of a bonus system for employees with distinguished performance
	10.4 Existence of structured rewards and recognition module with a metric measure
Managers' and employees' awareness of LSS tools and techniques	11.1 Support attending workshops and seminars related to LSS
	11.2 Encourage employees to use LSS tools
	11.3 Managers are fully aware of LSS benefits
	11.4 Managers and employees have certificates related to LSS
Project management skills	12.1 Prioritize LSS improvement projects
	12.2 Improvement actions for the LSS projects
	12.3 Provide enough resources to complete projects
	12.4 Utilize LSS tools for project cost reductions
Prioritise business quality	13.1 Focus on resource allocation and improvements in shipping time, product quality, and service quality
	13.2 Define business objectives by understanding customers' needs
	13.3 Facilitate communications within a team
	13.4 Focus on customer relation management
Adoption of Quality 4.0 within Industry 4.0	14.1 Utilize an advanced software/application with the capability to auto-adjust processes
	14.2 Existence of barcoded and RFID-enabled inventory system
	14.3 Use of big-data analysis and prediction system
	14.4 Use of enterprise resource planning (ERP) system

To assess the content validity of the items, two academics reviewed the questionnaire's items. They assessed the questions based on clarity, length, and the time required to complete the survey. Then the final version of the questionnaire items was finalised.

A reliability test was used to evaluate the questionnaire items. The results showed that the Cronbach's alpha value was greater than 0.7, which indicated that the measurement scale used in this study was consistent, as shown in Table 5.

Table 5: Reliability test for questionnaire items

No.	Factor	No. of items	Cronbach's alpha (α)
1	Top management support and commitment	4	0.86
2	Advanced tools for communication and information flow	4	0.84
3	Teamwork and collaboration	4	0.76
4	Organisational culture and structure	4	0.77
5	Employees' development and engagement	4	0.89
6	Understanding customers' requirements	4	0.72
7	Cooperative supplier relationships	4	0.76
8	Strategic quality planning	4	0.79
9	Linking LSS with customer satisfaction and business strategy	4	0.71
10	Adopting a recognition and reward system	4	0.83
11	Managers' and employees' awareness of LSS tools and techniques	4	0.78
12	Project management skills	4	0.88
13	Prioritise business quality	4	0.76
14	Adoption of Quality 4.0 within Industry 4.0.	4	0.85

3.5. Principal component analysis

The Statistical Package for Social Sciences (SPSS) software was used to perform the principal component analysis (PCA). According to Fodor [57], PCA is a statistical technique for variable reduction that obtains uncorrelated variables and identifies strong components in the data. The components with eigenvalues greater than 1.0 should be considered [58]. Table 6 shows that four components extracted from the data accounted for 76 per cent of the total variation.

Table 6: Results of principal component analysis

Comp.	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	2.556	33.722	33.722	2.556	33.722	33.722	2.553	29.198	29.198
2	1.966	18.878	52.600	1.966	18.878	52.600	2.123	14.296	43.494
3	1.447	12.551	65.151	1.447	12.551	65.151	1.879	10.882	54.376
4	**1.209**	**10.433**	**75.584**	**1.209**	**10.433**	**75.584**	**1.209**	**9.007**	**63.383**

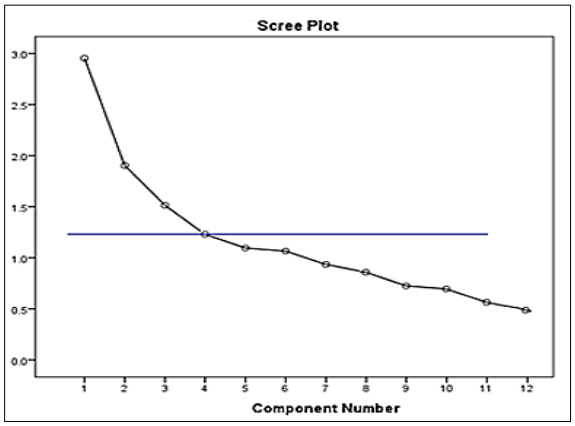

Figure 1: Scree plot

The Kaiser–Meyer–Olkin (KMO) test was used to check sampling adequacy. The cut-off value should be equal to or greater than 0.6 [50]. The estimated KMO test result was 0.77, indicating that the PCA could extract the common factors. The results in Table 7 show that four components made significant contributions to the total variability. The first component contributed 33.72 per cent of the total variance and included four items (Q1.1, Q1.2, Q10.1, Q4.2). These items related to 'Adopting a recognition and reward system', 'Organisational culture and structure', and 'Leadership support and management structure'. Thus the first factor was labeled 'Leadership support'. The second factor contributed 18.88 per cent of the total variance, and contained three items (Q14.2, Q2.1, Q14.1). These belonged to 'Adoption of Quality 4.0 within Industry 4.0' and to 'Advanced tools for communication and information flow'. Thus the second factor was labeled 'Technological capabilities'. The third factor contributed 12.55 per cent of the total variance and covered two items (Q11.3, Q6.2). This factor was subject to 'Managers' and employees' awareness of LSS tools and techniques' and to 'Understanding of customers' requirements'. Accordingly, the factor was identified as 'Knowledge acquisition'. Finally, the fourth factor contributed 10.43 per cent of the total variance, and was associated with the Q3.1 and Q5.2 items. This factor represented 'Teamwork and collaboration' and 'Employees' development and engagement'. So the factor was called 'Creativity and innovation'. A further explanation of these factors is given in the next section.

Table 7: Rotated factors

Component	1	2	3	4
Q 14.2	-.049	.665	.019	**-.002**
Q 2.1	.186	.830	-.187	**-.013**
Q 8.3	.160	.154	.228	**-.104**
Q 3.1	-.018	.115	.305	**.644**
Q 14.1	.028	.848	.184	**-.023**
Q 11.3	.111	.081	.820	**-.013**
Q 1.1	.831	-.098	.172	**.113**
Q 1.2	.623	.190	-.027	**.368**
Q 13.1	.283	.358	.451	**-.107**
Q 6.2	.013	-.076	.699	**.125**
Q 5.2	.071	-.160	-.122	**.820**
Q 10.1	.741	.062	.403	**-.007**
Q 4.2	**.751**	**.068**	**-.178**	**-.177**

3.6. Identification of critical success factors for implementing lean six sigma in the Kingdom of Saudi Arabia's small and medium-sized enterprises

Based on the PCA results, the CSFs were divided into four main categories.

The first CSF is related to 'Leadership support and management structure'. This factor has the greatest influence on the value of a small business. [56] demonstrated that senior managers are responsible for a company's quality initiatives and deployment. According to [59], leaders can establish an organisational culture that facilitates the implementation of LSS. Indeed, because SMEs have limited capital investment and human resources compared with large ones, top management must use the benefits of LSS and collect the required resources to make it a success. This includes investing resources in training and in capabilities that could facilitate a culture of data-driven decision-making and the development of an internal data system to store and access information quickly. [13] showed that leaders in the SME context should involve all of their employees in process improvement projects by using LSS tools, which could lead to the development of personal skills in problem-solving. Leaders of SMEs could take advantage of the adaptability and flexibility of SMEs to create customer satisfaction. According to [60], the success of SMEs depends mainly on their leadership skills, unity, management, liability, and risk. To succeed in implementing LSS in SMEs, leaders have the main role of creating a good environment for creativity, innovation, and quality improvement. This would include encouraging employees to participate in LSS projects, providing good training and mentoring of projects through team leaders, establishing a reward and recognition system, allowing employees to focus on process-related improvements, and data-based decision-making.

The second CSF belongs to 'Technological capabilities'. Most SMEs do not adopt digital transformation in the business process, unlike large businesses. Several studies have shown the lack of the use of technology in SMEs, which hinders their success. For instance, [61] stated that SMEs should integrate advanced technologies into their operations and procedures in order to achieve a competitive advantage in the market. This would result in improved productivity, reduced costs, and effective communication, and would facilitate the decision-making process. Indeed, Industry 4.0 is driven by enormous changes in manufacturing practices, processes, and innovation. Thus SMEs should use advanced software/applications and tools such as the Internet-of-Things (IoT), artificial intelligence (AI), machine learning, data mining, and robotics through the digitalisation and automation of the business process to achieve improved quality, customer satisfaction, and business excellence [62,63]. [56] demonstrated that the technological dimension is a significant factor in the successful implementation of LSS in SMEs.

The third CSF is attributed to 'Knowledge acquisition'. Training and skills are less likely to be available to employees in SMEs than in large businesses. In addition, SMEs face many difficulties in the market, such as an inability to retain qualified employees, limited expenditure on research and development (R&D), a lack of advanced technological systems, low managerial capabilities, and a lack of knowledge of local and international enterprises [64]. The implementation of LSS in SMEs is impacted by the high costs of transitions, inadequate financial planning, and the unstable economic environment. Thus SMEs could overcome these problems by spreading the knowledge of LSS methodology and tools to their employees, identifying the specific training needs related to LSS, and being aware of the increasing demand for skilled labour. Indeed, enhancing knowledge and developing employees' skills and should be aligned with the organisation's strategic plans and improvement programmes.

The fourth factor is assigned to 'Creativity and innovation'. The growing number of SMEs that seek a competitive advantage have shaped different ways of innovating, including connecting business process development with automation and digitalisation. The failure to capture and manage innovation is one of the reasons that SMEs fail in business [65]. The absence of innovation prevents SMEs from reducing their operational complexity and from focusing on the core principles and objectives of the business. Managing innovation involves identifying the areas for continuous improvement, reducing costs and waste, creating an appropriate environment to assist in the use of LSS tools, and transforming creative ideas into new products and processes. According to [66], innovation is one of the main criteria for improving organisational performance. [67] identified two types of innovation in SMEs: incremental innovation and radical innovation. Incremental innovation aims to improve the existing characteristics of a product or service that is offered to customers. In contrast, radical innovation focuses on developing new products or services to create customer satisfaction. As a result, most SMEs focus mainly on incremental innovation because of the absence of product enhancement and the non-availability of technological resources [68].

SMEs could support and motivate their employees in generating creative ideas and forming a quality culture, and so achieving a competitive advantage and growth. [69] identified the relationship between innovation and business success, and concluded that companies' sales increased when they promoted new products in the market; that innovation has been the main factor in the success of Japanese companies; that double the profit can be obtained by using innovative ideas and making significant improvements to their performance by adopting innovation; and that SMEs can sustain their business and grow faster than non-innovative companies.

4. CONCLUSION

This study has proposed the main CSFs for the successful implementation of LSS in the KSA's SMEs. An initial list of 29 factors was identified from the extensive literature. These factors were refined to produce a list of 14 factors. Then a PCA was conducted to identify the CSFs for LSS implementation in the KSA's SMEs. The results showed that four main factors influence Saudi SMEs' success in adopting LSS in their business processes: leadership support and management structure, technological capabilities, knowledge acquisition, and creativity and innovation. The study suggests that success is tied to top management support and to the development of an organisation's management structure.

SMEs should make the effort to develop a standardisation of quality, improve their procedural methods to provide better services, and satisfy customers' expectations. This could be achieved by aligning their organisational goals with LSS projects. Resistance to change is indeed a hindrance to LSS implementation in SMEs, which means that the top management's involvement and employees' engagement is crucial to implementing LSS in SMEs.

Although much research has been conducted on the CSFs for LSS implementation in SMEs, this study specifically explores those in a Saudi context. The research data includes only one region of the KSA and represents the owners' or managers' points of view, which means that the interpretation of the results cannot be generalised. There is also a need to consider each country's characteristics while investigating the factors that lead to the successful implementation of LSS in SMEs.

The scope of the study has been limited to the Saudi context only; thus the results could vary if the identified CSFs were used in other countries.

In spite of the fact that this paper aimed to identify the CSFs of LSS implementation in a specific sector in Saudi Arabia, the sample size of 104 was rather small for achieving a reliable and valid result. In addition, the paper focused only on identifying the CSFs for LSS implementation in Saudi SMEs, and did not consider large companies. The insights gained from this study should assist LSS practitioners and academics to understand better the adoption and implementation of LSS in SMEs.

It is recommended that further studies be conducted to develop a framework for LSS implementation in SMEs in the context of Industry 4.0.

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RESEARCH METHODOLOGY

All of the procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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