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## **Analysis of critical success factors in robust service systems through fuzzy cognitive map**

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**Abstract:** This study aims to identify and analyse the critical success factors (CSFs) in robust service systems using the fuzzy cognitive mapping (FCM) approach. First, the factors or criteria affecting the robust service systems were identified through the literature review. Then, the cause-and-effect relationships of the factors and the effect of each factor in the robust design of the service systems were determined using the opinions of the panel of experts using the FCM approach. Findings show that 39 factors affect making a robust service system which can be classified into five categories based on the balanced scorecard (BSC) approach: social responsibility and stakeholder satisfaction, learning and growth of individuals, internal processes, finances, and suppliers. The three criteria of strengthening the process design, the competence of individuals and education and learning of individuals have the most significant impact on the robust design of the service system, respectively.

**Keywords:** service management; service quality; robust service systems; critical success factors; CSFs; fuzzy cognitive mapping; FCM.

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## 1 Introduction

Recent developments in the economy show that the service sector is growing and developing. Today, services are at the heart of every society's economic activity (Fitzsimmons et al., 2008). On the other hand, with the increase of unforeseen fluctuations in the business environment, customer satisfaction is of great importance. Customer satisfaction is the most critical consideration in the production or design of any product or service; because it plays a crucial role in business success (Gupta, 2018). Keeping existing customers satisfied increases potential customers and can maximise business profits (Ramacher and Mönch, 2014). Such an action to gain customer satisfaction must align with taking on social responsibility to society. Manufacturers believe that business success depends largely on the adaptability of the products and services to the wants or needs of the customers. Customer satisfaction can become a competitive advantage (Pamucar et al., 2021). Therefore, meeting customer needs and gaining customer satisfaction in a dynamic and unpredictable environment is significant (Shil et al., 2010). Many organisations and service companies must seek customer satisfaction to maintain and grow their existence (Wang and Qi, 2019). Service companies must design their operating system in such a way as to increase customer engagement and determine the critical role of service quality (Lee et al., 2019). Hence, service managers are under increasing pressure to show that their services are customer-oriented and committed to improving the quality of their services (Liang et al., 2009), which will effectively ensure the sustainability of social responsibility.

Service systems constantly change through customers, providers, suppliers, or unexpected events. However, customers want an upgraded integrated system to meet their expectations (Weiss and Goldberg, 2019). Robust design is one of the most widely used concepts in engineering, initially proposed by Taguchi (1986). The purpose of robust design in a system is to maintain the minimum quality acceptable to the customer under challenging situations or unpredictable conditions (Pamucar et al., 2021). A system that strives to deliver satisfactory quality, even when the situation is not normal, should focus on providing value to the customer in the long run. Thus, the Taguchi design concept can also be used for service systems, meaning that the system must be designed so that the risk of poor performance is minimised (Gaury and Kleijnen, 1998).

In general, the robust design of the service system is a multi-criteria issue. Multiple criteria are usually not equal in terms of importance, and their evaluation creates complex relationships. In most of the studies conducted to improve various quality criteria, traditional methods are used to determine the weights, but these methods cannot fully determine the relationship between the criteria of the service system and the level of satisfaction (Chen and Chuang, 2008). The fuzzy cognitive mapping (FCM) approach is one of the practical approaches that can help identify the relationships between indicators and factors affecting a process or system. This approach determines the amount of in-degree (ID) or out-degree (OD) factors affecting the robust design of a system against destructive and unforeseen factors. The present research provides a model for identifying the most important critical success factors (CSFs) affecting the robustness of the service systems. Hence, the contributions of this research can be divided into three categories:

- 1 Given that service systems are constantly changing through customers, service providers, suppliers, or unexpected events, the performance of a service system depends on the performance of a chain of processes in different operational areas, which in the Weiss and Goldberg (2019) study has not been reviewed. The present study tries to develop the Weiss and Goldberg (2019) study and study the robust design of services in the systems consisting of different functional dimensions and explain the concept of services robust design with a comprehensive and systematic approach.
- 2 Little research has examined the relationships and complexities of internal factors affecting service systems. In this study, by considering the number of potential factors affecting a system, various relationships and their internal complexity, the FCM approach has been used to provide a strategic path to succeed in the robust design of the service systems.
- 3 Identifying the factors affecting the performance of service systems, analysis and understanding of their relationships and internal complexities allow managers to take appropriate action to maintain the performance of service systems and reduce the harmful effects of the unforeseen environment.

This article is structured as follows: First, the existing literature on service systems and the factors affecting the robust design of service systems are described. Then, the research methodology and its main framework based on the FCM approach are introduced. The findings and discussion section states how to strengthen the service system's robustness by identifying the interrelationships of the influential factors. Finally, the conclusion section provides solutions for managers and future research.

## 2 Literature review

In this section, we first refer to the theoretical foundations of service systems' robust design, and then, according to the literature, we identify the factors affecting service systems' robust design. We also refer to the research gap that led to this research, or in other words, the research contributions.

### 2.1 *Service systems' robust design*

Processes are composed of various components such as input, output, several controllable factors, and uncontrollable factors that affect the input-to-output conversion operation (Weiss and Goldberg, 2019). Robust design involves the search for a design (product, process or system, etc.) that, instead of being suitable for a particular environment, ensures small changes and fluctuations in performance when changing the environment (Taguchi, 1986). Mayer and Benjamin (1992) offer six steps for robust design, of which identifying the factors and objectives is one of the most critical steps. These factors are classified into two categories: design factors and noise factors. Design factors are system-independent variables whose values are probably in the designer's control, while noise factors are not in the designer's control (Gaury and Kleijnen, 1998; Hong, 2012). According to Taguchi et al. (2005), a process or product is robust if it limits or reduces changes in the performance of a product or process in the presence of fluctuations or noises. Robust design methodology aims to design without sensitivity to change in different products and system environments (Bergman et al., 2009).

In this study, our definition of robust design in a system is to provide an acceptable quality to the customer even in difficult situations. Such a system can provide satisfactory quality to the customer in abnormal conditions and continuously strives to provide value to the customer in the long run. A robust service system continuously delivers the desired service results regardless of changes in service requests or external changes (Vargo and Akaka 2012; Weiss and Goldberg 2019). Social responsibility is an essential element of movement in such a system. Taguchi et al. (2005) believes that the most important issue in product design or process quality is its robustness to change. Thus, a robust system produces the desired results regardless of changes in inputs or unexpected events. In a service system, robust design means that the organisation consistently delivers value to the customer, irrespective of external factors beyond the manager's control. Analysing factors affecting operating systems and processes is very important to deal with unwanted and unpredictable changes and fluctuations. A proper understanding of the importance and impact of each of the factors under control in the process and its effects on the whole system can help managers reduce the destructive effects and prevent excessive fluctuations (Badinelli 2012). Therefore, understanding these factors and their complex relationships in a system is essential for managers and decision-makers. FCM is one of the efficient approaches in identifying the factors affecting the system, creating a robust process, and understanding the interactions of its internal factors. This approach helps managers find a strategic path to strengthen the robust design of the process or system by identifying causal factors.

## 2.2 Factors affecting the robust design of service systems

Quality of service is seen as an asset and a key factor in the performance of organisations on a financial as well as non-financial basis (Al-Hawari and Ward, 2006). Service quality is a concept that many studies have studied due to problems in its definition and measurement (Wisniewski, 2001; Yayla-Küllü et al., 2015). Zeithaml et al. (1996) defined service quality as the customer's perception of perceived services compared to other similar services. It is necessary to identify the dimensions and parameters that affect the robust design of service systems to create a comprehensive insight into it. Parasuraman et al. (1994) and Zeithaml et al. (1990) considered five dimensions, including reliability, responsiveness, trustworthiness, empathy, and tangibility, and developed the SERVQUAL scale as a service quality measurement method. This method has been developed to compare customers' expectations and perceptions of the actual services provided in a service encounter (Shahin et al., 2012). Stewart (2003) addressed the issue of service design to improve quality and provided a framework based on task, behaviour, and tangibility to organise the service quality literature to encounter design. This framework shows how successful services managers differentiate design issues and provides an opportunity to solidify the process against product vulnerabilities. Cook et al. (2002) addressed a wide range of questions related to the human aspect of service design, development, and deployment of new service technologies. They examined human development issues in the trilogy of service encounters – customers, contact personnel, and organisation. Shil et al. (2010) proposed a robust customer satisfaction model (RCSM) to ensure customer service quality satisfaction, using quality function deployment (QFD) to meet customer requirements, technical factors, and their interrelationships. Shahin (2007), in a study on robust design of Service Quality, sought to develop the best levels of service quality dimensions (SQDs) in airlines. He also provided an essential list of SQDs as essential customer services and needs elements. The appropriate design of service quality that considers robustness in service quality can be very desirable from the customers' point of view. Much research has been done on the design of the provision of services. These researches have focused on various goals, including generating more efficiency to better align with customer needs (Heskett and Sasser, 2010; Lee et al., 2019; Schmenner, 1986; Yom-Tov and Chan, 2021). In addition, various tools or approaches support effective service design (Pamucar et al., 2021; Stewart, 2003). This research tried to investigate a set of factors affecting different parts of a service system using a systematic and comprehensive approach. So that with the help of balanced scorecard (BSC) concept, he classified the set of factors affecting the service system from different dimensions of stakeholder satisfaction, internal process, learning and training, finance and suppliers. In general, by reviewing the relevant literature, 39 factors (criteria) affecting the robust design of the service systems were identified, classified into five categories according to the dimensions of the BSC approach. Table 1 shows the identified factors according to the references used. Also, the code assigned to each of these factors is shown in this table.

This research intends to use a FCM approach to comprehensively and integrally examine all identified factors or criteria and analyse their impact on a service system. In previous studies, only some criteria were studied in a limited way, but in the present study, all criteria are examined, which shows one of the innovations of this article.

**Table 1** Identifying the factors (criteria) affecting the robust design of the service systems according to the literature review

| Main criteria                                      | Sub-criteria                                                                                                                 | The number of used references |   |   |   |   |   |   |   |   |    |    |    |    |    |    | Code |
|----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|-------------------------------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|------|
|                                                    |                                                                                                                              | 1                             | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |      |
| Social responsibility and stakeholder satisfaction | The extent to which new customer needs are met                                                                               | ✓                             | ✓ |   |   | ✓ |   |   |   |   |    |    |    |    | ✓  | ✓  | SS1  |
|                                                    | Variety of orders                                                                                                            |                               | ✓ |   |   | ✓ |   |   | ✓ |   |    |    |    |    |    | ✓  | SS2  |
|                                                    | Ability to grow and create value                                                                                             | ✓                             |   |   |   | ✓ |   | ✓ |   | ✓ |    |    |    |    |    | ✓  | SS3  |
|                                                    | Ability to access and dynamic communication with the customer                                                                |                               |   |   |   | ✓ |   |   |   | ✓ |    | ✓  |    | ✓  |    | ✓  | SS4  |
|                                                    | Paying attention to security and confidentiality and respect for privacy                                                     | ✓                             |   |   |   |   | ✓ |   |   |   | ✓  | ✓  |    |    | ✓  | ✓  | SS5  |
|                                                    | Ability to specialise in how to behave and provide customer service                                                          | ✓                             |   |   |   | ✓ | ✓ | ✓ |   |   | ✓  |    |    |    | ✓  | ✓  | SS6  |
|                                                    | The degree of responsibility (Tendency to help the customer and accept any mistakes in providing timely and quality service) |                               |   | ✓ | ✓ |   | ✓ |   | ✓ |   | ✓  | ✓  |    | ✓  |    | ✓  | SS7  |
|                                                    | Timely delivery power without delay and error                                                                                | ✓                             |   |   |   |   | ✓ | ✓ | ✓ |   |    |    | ✓  |    |    | ✓  | SS8  |
|                                                    | Social efficiency (the ratio of the value of services produced to social effects)                                            | ✓                             |   | ✓ |   | ✓ | ✓ | ✓ | ✓ | ✓ | ✓  |    |    |    |    | ✓  | SS9  |
|                                                    | Invest in recruitment and employment                                                                                         |                               | ✓ |   |   | ✓ |   |   | ✓ |   |    |    |    |    |    | ✓  | LG1  |
| Learning and growing people                        | Learning and educating people                                                                                                |                               | ✓ |   |   | ✓ |   |   | ✓ |   |    |    |    |    |    | ✓  |      |
|                                                    | Flexibility in responding to change                                                                                          |                               |   |   |   |   |   |   |   |   |    |    |    |    |    | ✓  | LG2  |
|                                                    | Competence (skills/ knowledge/professionalism)                                                                               | ✓                             |   |   |   |   | ✓ | ✓ |   | ✓ |    |    |    | ✓  |    | ✓  | LG3  |
|                                                    | Motivation and mood of people                                                                                                |                               |   |   | ✓ |   |   |   | ✓ |   |    |    |    |    |    | ✓  | LG4  |
|                                                    | The degree of individual interaction with the system                                                                         | ✓                             | ✓ |   | ✓ |   |   |   |   |   |    | ✓  |    |    |    | ✓  | LG5  |
|                                                    | Awareness and understanding of the consequences of actions                                                                   |                               | ✓ |   |   |   |   |   | ✓ |   |    |    |    |    |    | ✓  | LG6  |

Notes: 1. Nouri et al. (2019); 2. Weiss and Goldberg (2019); 3. Su et al. (2013); 4. Stewart (2003); 5. Shil et al. (2010); 6. Shahin et al. (2012); 7. Morlock et al. (2014); 8. Macfarlane and Fager (1995); 9. Lagemann and Meier (2014); 10. Klibi et al. (2010); 11. Cook et al. (2002); 12. Kvet (2019); 13. Janáček and Kvet (2018); 14. Kvet and Janáček (2018); 15. Parnuear et al. (2021).

**Table 1** Identifying the factors (criteria) affecting the robust design of the service systems according to the literature review (continued)

| Main criteria               | Sub-criteria                                                                                                    | The number of used references |   |   |   |   |   |   |   |   |    |    |    |    |    |    | Present study | Code |
|-----------------------------|-----------------------------------------------------------------------------------------------------------------|-------------------------------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|---------------|------|
|                             |                                                                                                                 | 1                             | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |               |      |
| Learning and growing people | Identifying potential sources of variability                                                                    | ✓                             |   |   |   |   |   |   |   |   |    |    |    |    |    |    | ✓             | LG7  |
|                             | Power (ability) to understand complex situations                                                                | ✓                             |   |   |   |   |   |   |   |   |    |    |    |    |    |    | ✓             | LG8  |
|                             | The ability of people to think clearly in times of crisis                                                       | ✓                             |   |   |   |   |   |   | ✓ |   |    |    |    |    |    |    | ✓             | LG9  |
|                             | Awareness of the need and sources of its supply                                                                 | ✓                             |   |   |   |   |   |   |   |   |    |    |    |    |    |    | ✓             | LG10 |
| Internal process            | Strengthening process design                                                                                    | ✓                             | ✓ |   | ✓ |   |   |   |   |   | ✓  |    |    |    |    |    | ✓             | LG11 |
|                             | Process automation                                                                                              | ✓                             |   |   |   |   |   |   |   |   | ✓  |    |    |    |    |    | ✓             | IP1  |
|                             | System interaction with the environment                                                                         | ✓                             |   |   |   |   |   |   | ✓ |   |    |    |    |    |    |    | ✓             | IP2  |
|                             | Information flow speed rate                                                                                     | ✓                             |   |   |   |   |   |   |   | ✓ |    |    |    |    |    |    | ✓             | IP3  |
|                             | Ensuring compliance with safety and security regulations                                                        | ✓                             | ✓ |   |   |   | ✓ |   |   | ✓ |    |    |    |    | ✓  |    | ✓             | IP4  |
|                             | Real-time of doing work (the length of time the process takes to produce the service under standard conditions) |                               |   | ✓ |   | ✓ |   |   |   | ✓ |    |    | ✓  |    |    |    | ✓             | IP5  |
|                             | Waiting time in queue (the length of time the customers have to wait to receive the services)                   |                               |   |   |   |   |   |   | ✓ |   |    |    | ✓  |    |    |    | ✓             | IP6  |
| Finances                    | Increasing skills and strengthening process capacity planning                                                   | ✓                             |   |   |   |   |   |   |   | ✓ |    |    |    |    |    |    | ✓             | IP7  |
|                             | Process modification                                                                                            |                               |   |   | ✓ |   |   |   |   | ✓ |    |    |    |    |    |    | ✓             | IP8  |
|                             | Ability to fully meet customer needs (completeness)                                                             | ✓                             |   | ✓ |   |   | ✓ |   |   |   |    |    | ✓  |    |    | ✓  | ✓             | IP9  |
|                             | Reducing cost                                                                                                   | ✓                             |   |   |   |   | ✓ |   |   | ✓ |    | ✓  | ✓  |    | ✓  |    | ✓             | IP10 |
|                             | Operational efficiency (Proper utilisation of capacity and resources in production and service delivery)        | ✓                             |   |   |   |   | ✓ |   |   | ✓ | ✓  | ✓  | ✓  | ✓  | ✓  |    | ✓             | F1   |
|                             | Energy resources efficiency (the ratio of the value of services produced to the energy consumed)                | ✓                             |   |   |   |   |   |   | ✓ |   |    |    |    |    |    |    | ✓             | F2   |
|                             | Asset and liquidity flow management                                                                             | ✓                             |   |   |   |   | ✓ |   |   |   |    |    |    |    |    |    | ✓             | F3   |
| Suppliers                   | Supplier efficiency                                                                                             |                               |   |   |   |   |   |   |   |   | ✓  |    |    |    |    |    | ✓             | F4   |
|                             | Careful selection of suppliers                                                                                  |                               |   |   |   |   |   |   |   |   | ✓  |    |    |    |    |    | ✓             | S1   |
|                             | Commitment of suppliers                                                                                         |                               |   |   |   |   |   |   |   |   |    |    |    |    |    |    | ✓             | S2   |
|                             | Diversity and multiplicity of suppliers                                                                         |                               |   |   |   |   |   |   |   |   |    |    |    |    |    | ✓  | ✓             | S3   |
|                             | Variety of demand and purchase order                                                                            |                               |   |   |   | ✓ |   |   |   |   |    |    |    |    |    | ✓  | ✓             | S4   |

Notes: 1. Nouri et al. (2019); 2. Weiss and Goldberg (2019); 3. Su et al. (2013); 4. Stewart (2003); 5. Shil et al. (2010); 6. Shahin et al. (2012); 7. Morlock et al. (2014); 8. Macfarlane and Eager (1995); 9. Lagemann and Meier (2014); 10. Klibi et al. (2010); 11. Cook et al. (2002); 12. Kvet (2019); 13. Janáček and Kvet (2018); 14. Kvet and Janáček (2018); 15. Pamucar et al. (2021).

### 2.3 Research gap

Meeting customer expectations and providing the minimum acceptable quality to customers in dynamic and unforeseen conditions is one of the most critical challenges for service organisations. Few studies have been conducted on the design and maintenance of the service systems in dynamic and unforeseen conditions. Hence, the research gap of this research can be divided into three categories:

- 1 Weiss and Goldberg (2019) explained the concept of robust services using a comparison of the concept of person-oriented and process-oriented. They expressed the importance of being process-oriented in forming the robust design of services. Given that service systems are constantly changing through customers, service providers, suppliers, or unexpected events, the performance of a service system depends on the performance of a chain of processes in different operational areas, which in the Weiss and Goldberg (2019) study has not been reviewed. The present study tries to develop the Weiss and Goldberg (2019) study and study the robust design of services in the systems consisting of different functional dimensions and explain the concept of services robust design with a comprehensive and systematic approach.
- 2 So far, very few studies have been conducted to identify the factors affecting the robust design of the service systems. In this regard, we can refer to the study of Shahrin et al. (2012), Morlock et al. (2014) and Lagemann and Meier (2014), which have examined only a small number of factors from the perspective of customer satisfaction. In contrast, the present study has tried to comprehensively examine all environmental factors under control and those affecting the various functional areas of a system, especially the stakeholders' satisfaction and social responsibility, to improve the robust design of the service systems in unforeseen circumstances.

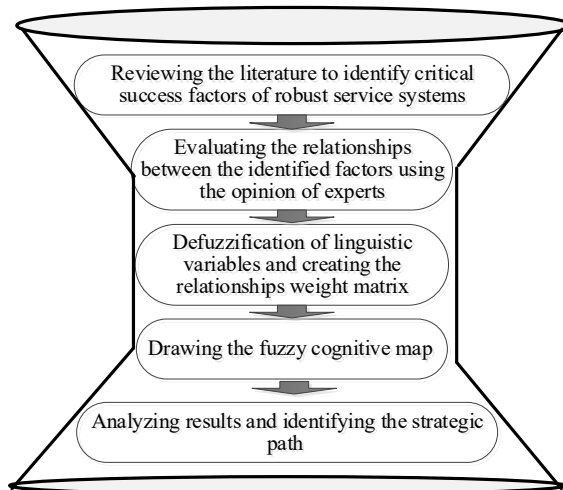
## 3 Research Methodology

The statistical sample of this study is ten academic and industrial experts in the service management area in Bushehr province, Iran, who have specialised knowledge, work experience and the necessary knowledge of new developments in the robust design of service systems. These experts have been selected using the snowball method, and their opinions have been used to weigh the indicators using a two-by-two comparison matrix of criteria. The demographic information of these experts is shown in Table 2.

In this research, Scopus and Web of Science databases have been used in the years 1990 to 2020 in order to investigate the literature review in the field of robust service system. The keywords robust service, robust service system, service system and robust design were used to search in these databases. In this study, first, by reviewing the literature in the field of service systems, the CSFs affecting the robust design of service systems were extracted. Then the opinions of experts were used to evaluate the relationships between the identified factors. In the next step, the FCM approach was used to investigate the causal relationships of the specified criteria. Finally, according to the analysis of FCM findings, a strategic path was presented to achieve the robust design of the service systems. The implementation steps of the research are shown in Figure 1.

**Table 2** The demographic information of experts

|                            |                       | <i>Number</i> | <i>Percentage</i> |
|----------------------------|-----------------------|---------------|-------------------|
| Activity area              | University            | 5             | 0.50              |
|                            | Industry              | 5             | 0.50              |
| Education                  | PhD                   | 7             | 0.70              |
|                            | MSc                   | 2             | 0.20              |
|                            | BSc                   | 1             | 0.10              |
| Field of study             | Business management   | 4             | 0.40              |
|                            | Industrial management | 6             | 0.60              |
| Work experience<br>(years) | more than 15          | 2             | 0.20              |
|                            | 10–15                 | 4             | 0.40              |
|                            | less than 10          | 4             | 0.40              |

**Figure 1** Research implementation steps

### 3.1 Fuzzy cognitive mapping approach

The FCM approach has been used to analyse the research data. A FCM is a symbolic diagram that can describe and model the systems with high uncertainty and uses a reasoning method similar to human reasoning. This diagram includes nodes (concepts or criteria) and weight arcs between these nodes. The concepts in a FCM model describe the behaviour of a system, and the weighted arcs with a sign indicate the strength of the causal relationships between the indices (Amirkhani et al., 2020). Experts are first asked to express their comments using linguistic variables. Fuzzy linguistic scales are then interpreted into fuzzy numbers according to the information provided by experts (Poomagal et al., 2021). The linguistic variables and fuzzy numbers used in this research are shown in Table 3.

**Table 3** Linguistic variables used in the research and their related fuzzy numbers

| Linguistic variables | Very high    | High           | Medium            | Low            | Very low     |
|----------------------|--------------|----------------|-------------------|----------------|--------------|
| Fuzzy numbers        | (0, 0, 0.25) | (0, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 1) | (0.75, 1, 1) |

Source: Sufiyan et al. (2019)

In this study, the process of fuzzy and defuzzification transformations, which is usually performed directly by the researcher to convert the actual values of the system to the values of the concepts of the map and the weight of cause and effect relationships (Sufiyan et al., 2019); It has been done by fuzzy mean method (Sufiyan et al., 2019) which is calculated based on equation (1):

$$A = (w_l^{(1)}, w_m^{(1)}, w_u^{(1)}) \quad i = 1, 2, \dots, n \quad (1)$$

$$A_{avf} = \frac{(w_l^{(1)}, w_m^{(1)}, w_u^{(1)}) + \dots + (w_l^{(n)}, w_m^{(n)}, w_u^{(n)})}{n} = \frac{\sum_{i=1}^n (w_l^{(i)}, w_m^{(i)}, w_u^{(i)})}{n}$$

$$W_{ij} = \frac{w_l + 4w_m + w_u}{6}$$

Therefore, the extent of the effect of the concept of  $C_i$  on the concept of  $C_j$  is obtained by defuzzification of the set of fuzzy values determined by experts. Finally, the initial weights matrix (W) is created (Amirkhani et al., 2020). The matrix of weights (W) in the FCM is a square matrix  $n \times n$ , shown in Figure 2.  $W_{ij}$  in this matrix is in the range  $[-1, 1]$ . If the value of the causality weight between the concepts  $C_i$  and  $C_j$  are positive ( $W_{ij} > 0$ ); In this case, increasing the value of the concept of  $C_i$  increases the value of the concept of  $C_j$ , and decreasing the value of  $C_i$  leads to decreasing the value of  $C_j$ .

When there is a negative causality between the two concepts ( $W_{ij} < 0$ ); In this case, increasing the value of the concept of  $C_i$  decreases the value of the concept of  $C_j$ , and decreasing the value of  $C_i$  leads to increasing the value of  $C_j$ . If there is no relationship between the two concepts,  $W$  equals zero ( $W_{ij} = 0$ ) (Yang and Peng, 2009).

$$\begin{matrix} & C_1 & C_2 & C_3 & \cdots & C_n \\ \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_{n-1} \\ C_n \end{matrix} & \begin{bmatrix} 0 & w_{12} & w_{13} & \cdots & 0 \\ 0 & 0 & w_{23} & \cdots & w_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ w_{(n-1)1} & 0 & 0 & \cdots & 0 \\ w_{n1} & 0 & w_{n3} & \cdots & 0 \end{bmatrix} \end{matrix}$$

Methods developed in the framework of graph theory, such as FCM, allow researchers to analyse the structural features (Çoban and Seçme, 2005). One of the structural features of this method is its density; the number of available arcs divided by the maximum number of all possible arcs represents this index (Satama and Iglesias, 2020). It should be noted that FCMs made by humans usually have a density in the range of 30% to 40% (Poczeta

et al., 2017). The density index is calculated according to equation (2) when  $n$  and  $m$  represent the number of indices and arcs, respectively.

$$D = \frac{m}{n(n+1)} \quad (2)$$

Graph theory indicators also provide a way to describe FCM structures using three indicators of ID, OD, and centrality (Solana-Gutierrez et al., 2017). As the purpose of this study is to identify the main causes (i.e., underlying causes in a causal map), the role of each of the criteria in the map should be carefully considered. The weight matrix  $W$  makes it possible to analyse the role of criteria in the FCM and states how each criterion is directly related to other criteria. For each criterion, the amount of ID, OD, and centrality ( $C$ ) are defined. The amount of ID shows the sum of the output arcs from the criterion and is calculated according to equation (3) (Soner et al., 2015).

$$od(i) = \sum_{j=1}^n |W_{ji}| \quad (3)$$

On the other hand, the amount of OD indicates the cumulative power of the input arcs to the criteria and is calculated according to equation (4) (Soner et al., 2015).

$$id(i) = \sum_{j=1}^n |W_{id}| \quad (4)$$

Centrality related to the weight of the criteria shows the strength of the connection between the criteria. In other words, it provides information on how a criterion contributes to the FCM (Sacchelli, 2014). According to equation (5), centrality is derived from the sum of the values of ID and OD of the criteria (Çoban and Seçme, 2005).

$$C(i) = id(i) + od(i) \quad (5)$$

**Figure 2** The weights matrix of the fuzzy cognitive map

$$\begin{matrix} & C_1 & C_2 & C_3 & \dots & C_n \\ \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_{n-1} \\ C_n \end{matrix} & \left[ \begin{array}{ccccc} 0 & w_{12} & w_{13} & \dots & 0 \\ 0 & 0 & w_{23} & \dots & w_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ w_{(n-1)1} & 0 & 0 & \dots & 0 \\ w_{n1} & 0 & w_{n3} & \dots & 0 \end{array} \right] \end{matrix}$$

## 4 Findings

According to the literature review, 39 CSFs of robust design of service systems were identified at first. According to the BSC approach's dimensions, these factors were classified into five categories of social responsibility and stakeholder satisfaction,

learning and growing people, internal processes, finances, and suppliers. Then, the effect of each criterion on the other criterion was obtained using a pairwise comparisons matrix based on the opinions of 10 experts with the linguistic words Lack of impact, very low, low, medium, high, and very high. The data obtained from interviews with experts were entered into Excel, and after defuzzification of data, a  $40 \times 40$  matrix was created (Appendix 1). In the next step, the colour of the criterion related to each of the dimensions of the robust service system was determined, and a cognitive map of robust service management was drawn using Gephi software. Figure 3 shows the cognitive map of the robust design of the service systems. In this figure, the size of each node is proportional to the effect of each criterion on the whole FCM.

**Figure 3** Cognitive map of robust design of the service systems (see online version for colours)

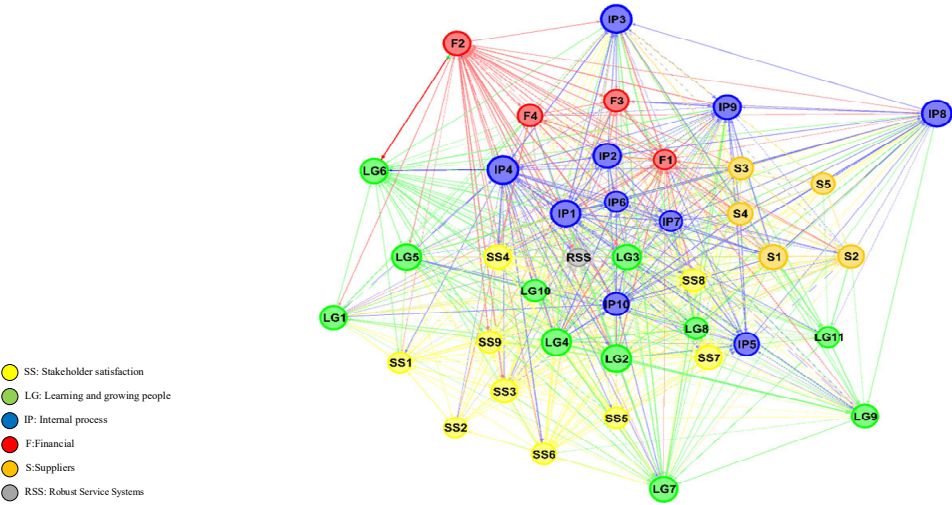


**Table 4** Prioritisation of criteria in the cognitive map based on their impact

| Criterion | Indegree | Outdegree | Centrality | Net impact |
|-----------|----------|-----------|------------|------------|
| IP1       | 20.16    | 7.94      | 28.1       | 12.22      |
| LG4       | 19.42    | 3.08      | 22.5       | 16.34      |
| LG2       | 19.07    | 6.16      | 25.23      | 12.91      |
| IP3       | 17.42    | 8.45      | 25.87      | 8.97       |
| IP4       | 17.19    | 7.24      | 24.43      | 9.95       |
| S1        | 14.34    | 7.68      | 22.02      | 6.66       |
| LG5       | 13.99    | 6.86      | 20.85      | 7.13       |
| IP2       | 13.72    | 4.23      | 17.96      | 9.49       |
| IP9       | 13.05    | 9.03      | 22.08      | 4.02       |
| LG3       | 12.84    | 12.45     | 25.29      | 0.39       |
| F2        | 12.65    | 13.43     | 26.08      | -0.78      |
| SS3       | 11.46    | 12.37     | 23.83      | -0.91      |
| SS4       | 11.07    | 10.69     | 21.77      | 0.38       |

**Table 4** Prioritisation of criteria in the cognitive map based on their impact (continued)

| <i>Criterion</i> | <i>Indegree</i> | <i>Outdegree</i> | <i>Centrality</i> | <i>Net impact</i> |
|------------------|-----------------|------------------|-------------------|-------------------|
| LG6              | 10.57           | 10.23            | 20.81             | 0.34              |
| LG7              | 9.73            | 11.26            | 20.99             | -1.53             |
| S4               | 9.66            | 2.49             | 12.15             | 7.17              |
| SS7              | 9.62            | 16.53            | 26.14             | -6.91             |
| IP10             | 8.63            | 11.98            | 20.60             | -3.35             |
| LG1              | 8.58            | 2.87             | 11.44             | 5.71              |
| LG9              | 7.83            | 7.07             | 14.89             | 0.76              |
| SS8              | 7.53            | 18.18            | 25.70             | -10.65            |
| F3               | 7.51            | 8.20             | 15.71             | -0.69             |
| S2               | 7.34            | 8.93             | 16.28             | -1.59             |
| S3               | 6.99            | 7.74             | 14.73             | -0.75             |
| F4               | 6.80            | 6.02             | 12.82             | 0.78              |
| IP8              | 6.35            | 7.77             | 14.12             | -1.42             |
| SS9              | 6.11            | 18.21            | 24.31             | -12.1             |
| IP5              | 6.02            | 8.76             | 14.78             | -2.74             |
| LG10             | 5.94            | 4.66             | 10.60             | 1.28              |
| SS5              | 5.93            | 8.60             | 14.53             | -2.67             |
| LG8              | 5.61            | 9.20             | 14.80             | -3.59             |
| SS6              | 5.24            | 14.39            | 19.63             | -9.15             |
| IP6              | 5.04            | 7.05             | 12.09             | -2.01             |
| SS1              | 4.32            | 9.95             | 14.27             | -5.63             |
| F1               | 4.18            | 14.14            | 18.32             | -9.96             |
| SS2              | 4.16            | 5.00             | 9.15              | -0.84             |
| IP7              | 4.06            | 9.94             | 14.00             | -5.88             |
| LG11             | 3.76            | 6.38             | 10.13             | -2.62             |
| S5               | 3.62            | 1.09             | 4.71              | 2.53              |
| RSS              | 0.00            | 21.24            | 21.24             | -21.24            |

Then, the criteria matrix was entered into FCM software, and the FCM was examined based on graph theory. The output of this software showed that the FCM has a density of 50%, which indicates the high complexity of this issue. Another output of this software was the amount of three indices of ID, OD, and centrality related to each criterion in the whole FCM; their values for each criterion are shown in Table 4. This table also shows the net impact obtained from the difference of ID and OD of the criteria. In this table, the criteria are arranged in order of ID index. The results showed that the three criteria of strengthening process design (IP1), competence (skills/knowledge/professionalism) (LG4) and learning and educating people (LG2) have the most outstanding ID amount on the robust design of service systems, respectively. Therefore, if service managers want to provide a service in a consistent way that satisfies their customers, they must first focus and policy on these three criteria. These criteria are usually under the control of management, which is an advantage for managers. In addition, the three criteria that had

the most amount of OD in the cognitive map were social efficiency (SS9), timely delivery power without delay and error (SS8) and commitment to the responsibility of service providers (SS7). These criteria have a high capacity to be influenced by other criteria of cognitive mapping; therefore, managers should pay special attention to the criteria affecting these criteria when policy-making. Today, social responsibility is one of the pillars of the principles of system sustainability, which in this study has been identified as an appropriate achievement under the control of criteria with impact. The third index to compare the criteria was the degree of centrality, obtained from the sum of the ID and OD of each criterion. The results related to centrality showed that the four criteria of process design (IP1), commitment to the responsibility of service providers (SS7), operational efficiency (F2) and system interaction with the environment (IP3) are highly centralised. These four criteria have the highest interaction with other FCM criteria.

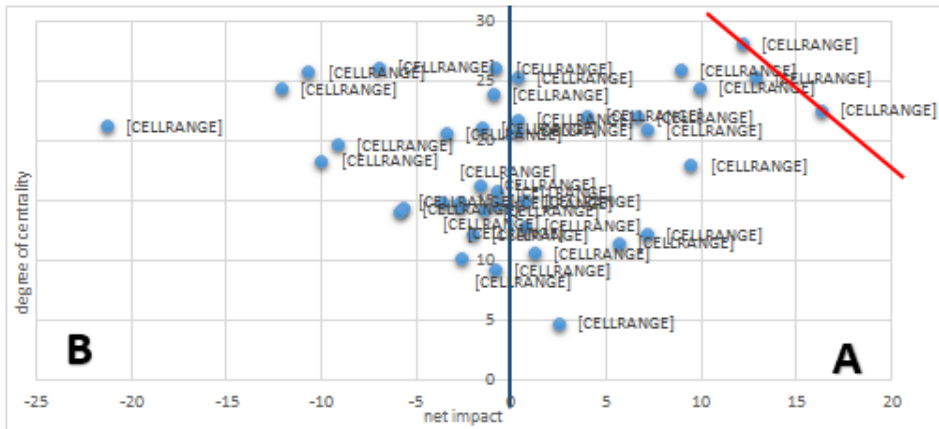
## 5 Discussion

Service systems constantly face serious challenges to maintain customer performance and satisfaction through internal, external or unforeseen factors. Maintaining the quality of services and meeting the expectations of stakeholders, especially the realisation of their social responsibility to society in different and unexpected situations, is challenging and complex (Weiss and Goldberg 2019; Heinrich et al., 2015). Therefore, the present study sought to identify the critical factors for the success of service systems' robust design. Paying attention to and strengthening these factors or criteria in designing service systems can increase the necessary capability to maintain system performance, provide quality to the customer, and help the system maintain the organisation's values even in strenuous and unusual conditions. The present study continues Weiss and Goldberg's (2019) study. The difference is that Weiss and Goldberg (2019) focused only on individuals and processes to achieve robust services and argued that the process-oriented is very important in achieving sustainable services. However, in this study, an attempt was made to examine a set of factors affecting different parts of the service systems using a systematic and comprehensive approach. Based on the findings of the present study, three criteria of strengthening process design (IP1), competence (skills/knowledge/professionalism) (LG4), and learning and educating people (LG2) are the most influential factors on the robust design of service systems. Managers with knowledge of the criteria affecting customer satisfaction and strengthening the social responsibility of service systems can make better decisions and allocate their resources in such a way as to improve the quality of products and customer satisfaction to the maximum possible.

In this study, the *Matrice d'Impacts Croisés Multiplication Appliquée à UN Classement* (MICMAC) method was also used to classify the factors or criteria affecting the robust design of service systems. In this method, the factors or criteria affecting the robust design of service systems were classified into two categories A and B, based on the degree of centrality (interaction of each criterion with other criteria) and net impact (Figure 4). Class A includes criteria that have a net positive impact and are considered complete and definite causal or effective criteria. The importance of these factors is that they have a high potential in the robust design of service systems. The high impact of these factors leads to the improved robust design of systems, and managers can focus on these factors to make better decisions. Among the criteria of this category, three criteria

of strengthening process design (IP1), competence (skills/knowledge/professionalism) (LG4), and learning and educating people (LG2) can be introduced as the essential criteria of research due to high interaction with other criteria and high net impact. Category B includes criteria that have a net negative impact. these criteria are complete OD or effect. These criteria must be carefully managed, which is difficult and complex. Managers must pay attention to other criteria that affect them when deciding to control them. This category includes criteria F1, SS9, SS6, SS7, SS8, SS1, S1, IP7, IP10, LG7, LG8, S2, and F2.

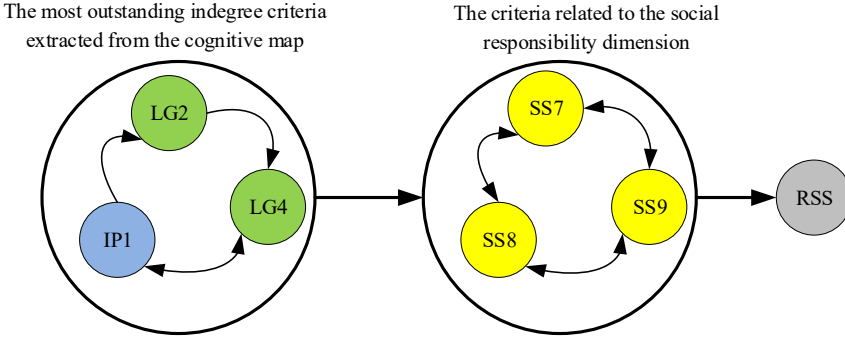
**Figure 4** The MICMAC diagram (see online version for colours)



### 5.1 The managerial implications

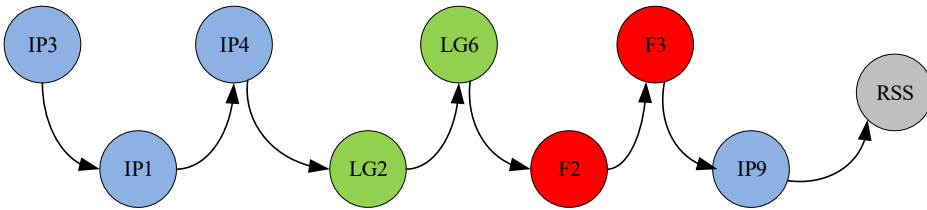
According to the research findings, the cognitive map of service systems' robust design has a high density and complexity. The complexity of the research problem and the cause-and-effect relationships of the factors double the need to plan and provide solutions to managers. Since the service systems aim to provide value to the customer and social responsibility, this study identified and introduced a strategic path for social responsibility and stakeholder satisfaction criteria by examining the cognitive map. Concerning the dimension of social responsibility and stakeholder satisfaction, it was found that the cognitive map was able to determine the relationship between the three criteria of social efficiency (SS9), the degree of responsibility (SS7), and timely delivery power without delay and error (SS8). As a set under the heading of social responsibility, these criteria are influenced by a series of critical criteria in the cognitive map. The critical criteria include learning and educating people (LG2), strengthening process design (IP1), and competency (skills/knowledge/ professionalism) (LG4). Figure 5 shows the strategic path related to the criterion of social responsibility and stakeholder satisfaction. According to this strategic path, it can be said that individual learning and training can be the central and underlying axis of strengthening the dimension of social responsibility, which is one of the pillars of the robustness of service systems.

**Figure 5** Strategic path related to social responsibility and stakeholder satisfaction (see online version for colours)



Then, to further analyse and provide suggestions to managers and decision-makers, a strategic path was provided by considering all the studied criteria to provide robust services (Figure 6).

**Figure 6** Strategic path related to the fuzzy cognitive map considering all the studied criteria (see online version for colours)



The strategic path obtained in Figure 6 indicates that the higher the degree of system interaction with the environment (IP3), the more significant the strengthening of process design (IP1); By strengthening the process design, which is one of the essential pillars of the service systems, the speed rate of information flow (IP4) also increases. As the flow of information in the service system increases, the key players in the service system must also adapt to these changes. As a result, the amount of learning and educating people (LG2) increases, and the more people learn, the more their interaction with the system (LG6). In the long run, this interaction will lead to the proper utilisation of capacity and resources in production and the creation of value in the provision of services, which leads to the operational efficiency (F2) and energy resources efficiency (F3); As a result, these interactions and efforts to increase service system efficiency enhance process modification (IP9), and ultimately the company can hope to provide robust service systems (RSS) to its customers. According to the proposed strategic path, the dimension of internal processes has the most significant impact on the robust design of service systems.

## 6 Conclusions

This study identified the CSFs of robust design of service systems using FCM approach and drew a suitable strategic path to success in this field.

Similarly, to Fedushko et al. (2021) research, this study used BSC approach to categorise the critical factors of services, but it added the supplier dimension.

Considering the impact of criteria on the robust design of service systems as well as the identified strategic path related to the dimension of social responsibility in the robust service systems (Figure 5); managers are advised to focus more on supporting the three criteria of strengthening process design (IP1), competency (skills/knowledge/professionalism) (LG4) and learning and educating people (LG2) to make more effective decisions and provide robust services to their stakeholders. Also, based on the identified strategic path concerning all dimensions (Figure 6), decision-makers in this field who decide to design a robust service system are recommended to implement policies to increase the interaction of the service system with the environment due to strengthening the process design of the service system and the speed of information flow, which increases the learning of people from the system and the extent of their interaction with the system. This process naturally increases operational efficiency and energy resources and efficiently improves the function.

### 6.1 Research limitations

This study tried to identify 39 indicators and classify them into five categories based on the BSC approach to examine the CSFs for the robust design of service systems. However, there may be other political, economic, and social factors that have not been addressed in this study. Also, in this study, the relationships between the ID and OD of the criteria have been based on experts' opinions. Expert opinions may change due to changes in the competitive environment of different industries at different time intervals.

### 6.2 Suggestions for future research

Future research can study how to strengthen and empower effective metrics in the proposed strategic path and help managers provide practical plans. Also, future research can analyse the variables identified in the proposed strategic path in more depth (in terms of different sub-criteria with a systemic perspective). Finally, it is suggested that future research pay more attention to the growth and development of human resources and its impact on strengthening the social responsibility of service systems and robust design of service systems.

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