Technological and Economic Development of Economy
ISSN: 2029-4913 / eISSN: 2029-4921
2022 Volume 28 Issue 6: 1818–1853
https://doi.org/10.3846/tede.2022.17734

DECISION-MAKING MODEL FOR DESIGNING TELECOM PRODUCTS/SERVICES BASED ON CUSTOMER PREFERENCES AND NON-PREFERENCES

Andrés CID-LÓPEZ [1], Miguel J. HORNOS [2*], Ramón Alberto CARRASCO [3], Enrique HERRERA-VIEDMA [4,5#]

[1]*National Telecommunications Corporation – Public Company, CNT EP, Quito, Ecuador*
[2]*Department of Software Engineering, University of Granada, Granada, Spain*
[3]*Department of Business Management and Marketing, Complutense University of Madrid, Madrid, Spain*
[4]*Andalusian Research Institute in Data Science and Computational Intelligence, University of Granada, Granada, Spain*
[5]*Department of Electrical and Computer Engineering, King Abdulaziz University, Jeddah, Saudi Arabia*

Received 19 October 2021; accepted 09 August 2022; first published online 27 October 2022

Abstract. The design of the packages of products/services to be offered by a telecom company to its clients is a complex decision-making process that must consider different criteria to achieve both customer satisfaction and optimization of the company's resources. In this process, Intuitionistic Fuzzy Sets (IFSs) can be used to manage uncertainty and better represent both preferences and non-preferences expressed by people who value each proposed alternative. We present a novel approach to design/develop new products/services that combines the Lean Six Sigma methodology with IFSs. Its main contribution comes from considering both preferences and non-preferences expressed by real clients, whereas existing proposals only consider their preferences. By also considering their non-preferences, it provides an additional capacity to manage the high uncertainty in the selection of the commercial plan that best suits each client's needs. Thus, client satisfaction is increased while improving the company's corporate image, which will lead to customer loyalty and increased revenue. To validate the presented proposal, it has been applied to a real case study of the telecom sector, in which 2135 users have participated. The results obtained have been analysed and compared with those obtained with a model that does not consider the non-preferences expressed by users.

Keywords: decision making, product/service design, product/service development, Lean Six Sigma, Intuitionistic Fuzzy Sets, user satisfaction, telecom sector.

JEL Classification: D81, D47, E27, L15, L86, L96, M31.

*Corresponding author. E-mail: *mhornos@ugr.es*
#Corresponding author. E-mail: *viedma@decsai.ugr.es*

Introduction

A fundamental problem among companies operating in the same sector of the economy is the struggle to achieve differentiation in the products/services (Ps/Ss) they provide. In mature markets, companies are in a general situation of lack of differentiation, since they offer very similar quality Ps/Ss with barely perceptible differences by customers (Jobber & Ellis-Chadwick, 2012). At this juncture, Market Orientation (MO) was formalized by Kohli (2017), as *the organization-wide generation of market intelligence pertaining to current and future customer needs*, *dissemination of the intelligence across departments*, *and organization-wide responsiveness to it*. Therefore, a key aspect for companies is to understand both the needs of their customers and the capabilities and plans of their competitors, through the acquisition and evaluation processes of market information in a systematic and anticipated way (Chen et al., 2015; Prajogo, 2016; Reim et al., 2015). Once costumers' needs are understood, suitable Ps/Ss can be developed specifically for them, which will lead to the much-desired differentiation and, consequently, customer loyalty.

As the information collected (from customers, employees, etc.) is not free of uncertainty, different authors (Cid-López et al., 2015, 2016, 2018; Saghaei & Didehkhani, 2011; Vinodh & Swarnakar, 2015) have found it convenient to use a fuzzy approach. This type of approaches has proven to be very useful in handling this information feature. We can say that the existing fuzzy approaches have MO, since they consider customer preferences as a key aspect for the improvement of either Ps/Ss or the business process in question. These preferences are usually modelled as belonging to previously defined fuzzy sets. In the case of the P/S packages offered by companies in the telecommunications sector, among the *preferences* to be considered by their clients could be, for example: high data volume (in Gb – Gigabytes) available in a mobile phone plan, the inclusion of high definition (HD) and standard definition (SD) channels at no additional cost in subscription TV plans, etc. Another key aspect to take into account would also be clients' *non-preferences*, among which would be, for example: the fulfilment of a permanence commitment with the operator that offers the telecom Ps/Ss if the user does not want to have economic penalties for changing operator before the end of the permanence period, or having to pay the costs associated with the installation and equipment lease of a certain service if the customer does not want to be subject to such commitment of permanence. However, we have not found any work in the literature that considers both preferences and non-preferences to determine clients' needs as a first step to offer them the Ps/Ss that best suit their particular needs.

In order to jointly model both preferences and non-preferences expressed by clients, we use Intuitionistic Fuzzy Sets (IFSs) (Atanassov, 1999), which can be considered both an extension and generalization of fuzzy sets. By considering not only the preferences, as most decision-making models do, but also the non-preferences expressed by clients, it is possible to better define the tastes and needs of each of them, as well as determine the P/S package or commercial plan that best suits their needs. As a result, the company will be able to provide each user with the most appropriate Ps/Ss, so it will be more valued by its clients, who will be more satisfied with the Ps/Ss received, as will be discussed in more detail in Section 5. IFSs have been applied to a wide variety of decision-making problems, as will be seen in the next section.

Moreover, we propose a new decision-making model that integrates IFSs into the Lean Six Sigma (L6σ) methodology (Corbett, 2011; Zhang et al., 2012a). This is because the main objective of L6σ is to eliminate all aspects that prevent or hinder Ps/Ss provided by a company from not meeting customer requirements. As L6σ arose from the combination of Lean and Six Sigma (6σ) methodologies (Chugani et al., 2017), it includes the following steps or phases coming from the latter: Define, Measure, Analyse, Improve and Control (DMAIC). This DMAIC structure, which has been frequently used for the design of Ps/Ss oriented to real customer needs (Williams et al., 2012) in market-oriented companies, is based on the collection and analysis of market information (Define, Measure, Analyse) as a key aspect prior to decision making (Improve), which should then be monitored (Control).

The idea behind our proposal is to apply the phases in the DMAIC structure to firstly identify or determine clients' needs considering both their preferences and non-preferences regarding the Ps/Ss provided by a given company, and then use the results obtained for the development of new Ps/Ss that meet their needs. Subsequently, some time after those new Ps/Ss have been launched on the market, it would be advisable to check customers' satisfaction with respect to the Ps/Ss they have purchased/contracted, in order to know if those Ps/Ss are truly suited to their needs, and to be able to offer them new products if necessary (e.g., if their needs have changed).

The combination of L6σ and IFSs in our proposal has a twofold objective. On the one hand, L6σ enables a systematic analysis of the information provided by customers with the aim of optimizing costs, both those related to the maintenance of the existing customer portfolio and those of acquiring new customers, which also includes the costs of attracting customers from competing companies. On the other hand, the use of IFSs allows us to know with greater precision the Ps/Ss that each client needs, thanks to the completion of a survey that must be answered with intuitionistic fuzzy numbers to collect both the preferences and non-preferences expressed by customers regarding the questions (relative to the features of the Ps/Ss offered or to be developed) included in it. This will enable the company in question to offer its customers the Ps/Ss that are closest to their needs and/or develop new Ps/Ss that meet their requirements. Thus, the company will achieve a higher client retention rate, since clients will be satisfied with the Ps/Ss it provides them, which also has an impact on the reduction of the aforementioned costs.

Finally, it should be noted that L6σ and IFSs hybridize and complement each other perfectly in our decision-making model. We can affirm that this is an original proposal, given that we have not found any reference in the literature that combines the use of the L6σ methodology with the fuzzy modelling of preferences and non-preferences. Moreover, to validate the proposed model, it has been applied to a real case study in which 2135 real customers of an existing telecommunications company have participated. This article also shows and analyses the results obtained, while comparing them with the results obtained with another approach that does not use the non-preferences expressed by customers.

The rest of the article is organized as follows: Section 1 presents a literature review regarding the four relevant facets included in our proposal: the design of Ps/Ss, which is its main goal, and the methodological and technical aspects considered, i.e., the L6σ methodology, the application of IFSs to decision-making problems, and the use of customers' non-preferences in addition to their preferences. Section 2 shows the definitions and main foundations used in our proposal. Section 3 describes in detail our proposal, which combines the L6σ methodology with IFSs. Section 4 applies the decision-making model proposed to a real case study in the telecommunications sector for the selection of the new Ps/Ss to be developed and launched on the market from a set of alternatives. Section 5 analyses and compares the results obtained by our model, which uses both preferences and non-preferences, with those obtained by another similar model, which only uses preferences, having applied both models to the aforementioned case study. Finally, the last section outlines the conclusions and future work.

1. Literature review

This section presents the results of a literature review on different aspects involved in our proposal. Firstly, we present the state-of-the-art on P/S design through a bibliographic mapping that aims to frame our proposal and place it within the main themes addressed in this field of research. Once our proposed model has been positioned within this study, we present the most relevant research papers related to the three main methodological and technical aspects contemplated in our proposal, which are: the L6σ quality methodology, the application of IFSs to decision-making problems, and the consideration of not only users' preferences but also their non-preferences.

1.1. State-of-the-art about design of Ps/Ss

As P/S design has been widely studied in the literature, we have focussed on the models or methodologies that allow this design in a systematic way, with the intention of framing our proposal among them. For this purpose, we have built a bibliometric map on this subject. The bibliometric mapping technique aims at displaying the structural and dynamic aspects of a given scientific research field in order to allow its interpretation. We have followed the methodology inspired by Cobo et al. (2012) and the SciMAT tool to obtain such a bibliometric map with data until the end of May 2022.

The first stage is data collection. In our case, we download the bibliographic data from the Web of Science core collection through the following query:

TS = ((“PRODUCT* DEVELOPMENT” OR “DEVELOPMENT OF PRODUCT*” OR “PRODUCT* DESIGN” OR “DESIGN OF PRODUCT*” OR “SERVICE* DEVELOPMENT” OR “DEVELOPMENT OF SERVICE*” OR “SERVICE* DESIGN” OR “DESIGN OF SERVICE*”) NEAR/2 (“METHOD*” OR “MODEL*” OR “SYSTEM*”))

which searches for papers containing the terms included in it within the following fields: title, abstract and keywords. This query returned 5,263 documents that were exhaustively reviewed by means of sampling. In the next step, called pre-processing, a standardization process was carried out by merging the plural and singular forms and converting the acronyms into their respective keywords, using Levenshtein distance in SciMAT. Besides, in this step, the terms implicit in the search itself, such as model, system, method, etc., were eliminated, as they were obviously the predominant ones in the analysis. After this, we carried out the remaining stages of the process: network extraction, normalization, mapping, analysis, and visualization. The strategic diagram obtained is shown in Figure 1. This diagram makes it possible to identify the importance of each theme according to two measures: *centrality* or external cohesion index (i.e., the degree of interaction of a network with other networks), and *density* or internal cohesion index (which is the intensity of the internal associations of a theme and represents its degree of development).

Based on this map, we finally interpret the results obtained. The clusters of themes most relevant and related to our proposal have been highlighted by adding a grey oval or circle around them, and are explained in more detail just below (diagrams with more detailed information about each of them can be found in the Appendix – Figures A1–A9):

- INNOVATION. This is a motor theme because innovation on P/S design is key and strategic for companies that want to have Ps/Ss differentiated from those of the competition, as indicated by Koskela-Huotari et al. (2021), among other many authors. Our proposal is framed within the strategic innovation decisions made by companies, since it provides a support tool for it. In addition, we will use balanced scorecard (Vijayan et al., 2021) to assess the outcomes of such strategic innovation decision makings.
- SATISFACTION. This is the other motor theme shown in the resultant strategic diagram, since organizations seek to satisfy customer through the quality of their Ps/Ss. This satisfaction is usually measured in terms of client perception. An example of this kind of research works is the one carried out by Pereira et al. (2019).

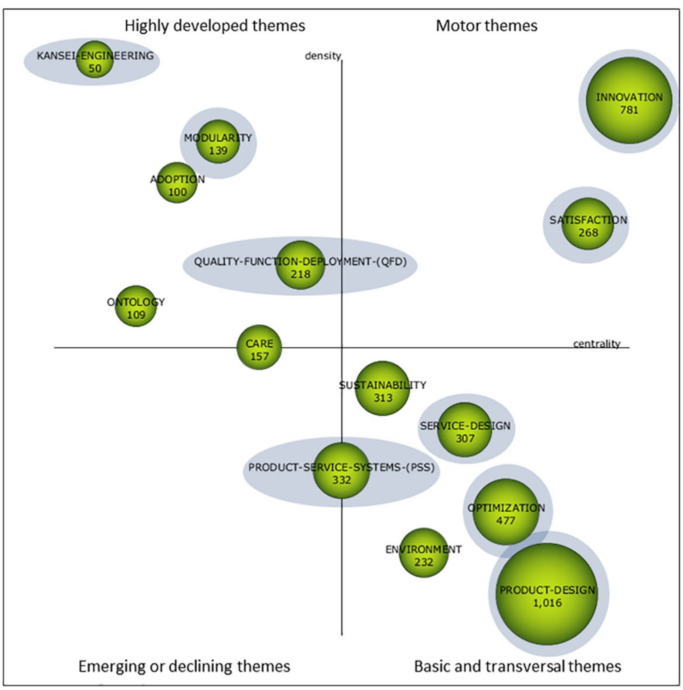

Figure 1. Strategic diagram based on papers related to design of Ps/Ss existing in the literature

- PRODUCT-DESIGN, SERVICE-DESIGN and PRODUCT-SERVICE-SYSTEMS. These are the three basic themes related to the design of products, services, or both together, which is the focus of our proposal. The first of these themes is related to uncertainty management, decision models and fuzzy logic, like our proposal. Regarding the second theme, we found themes related to co-design or co-creation and user experience (consult, e.g., Brunoe et al., 2020; Vink et al., 2021), also used in our proposal.
- OPTIMIZATION. This is other basic theme very related to our proposal, especially regarding cost reduction and possibility of simulation in the P/S design process. An example in this area is the work carried out by Du et al. (2019).
- QUALITY-FUNCTION-DEVELOPMENT (QFD). A systematic design process leads to the quality of Ps/Ss, and this cluster includes issues related to its measurement and assessment (see, e.g., Haber et al., 2020). In our case, the proposed model also contemplates this assessment. In this cluster, there are also other themes related our proposal, such as the use of fuzzy set theory, which takes into account customer requirements.
- MODULARITY. The modularity of Ps/Ss is essential to be able to adapt them to customer's needs (see, e.g., Lima & Kubota, 2022). In our own proposal, we model this modularity as the different criteria of a Multi-Criteria Decision-Making (MCDM) process.
- KANSEI-ENGINEERING. This is a methodology specifically directed to P/S design or improvement based on customer's feelings and needs (consult, e.g., Li et al., 2021; Roy et al., 2009). In our proposal, we use a similar philosophy through the L6σ methodology, where customers express their feelings and needs regarding certain features of Ps/Ss in the second phase of the methodology (i.e., Measure).

In this analysis, we have found many articles that use L6σ methodology to design new Ps/Ss considering customer preferences. However, we have not found any work that also considers their non-preferences. In the following subsections, we will go deeper into the most relevant published papers on the L6σ methodology and the mathematical tool we will use to jointly deal with both non-preferences and preferences of clients in that design process, i.e., IFSs.

1.2. L6σ methodology

Kaplan and Norton (2001) previously drew attention to the need to use measurement and monitoring tools, such as the Balance Scorecard (BSC), as a differentiating element to improve business performance. In this regard, the 6σ methodology (Tjahjono et al., 2010) arose, which uses a well-structured approach, known as DMAIC.

Afterwards, L6σ arose as a means of improving the quality of business processes in organizations (Psychogios et al., 2012; Salah et al., 2010). In L6σ, two methodologies are combined and complemented: Lean and 6σ. Both are used in resource optimization processes and in the reduction of activity variability, and are oriented towards customer satisfaction; therefore, they have MO. On the one hand, 6σ clearly benefits organizations in terms of improved operational efficiency, reducing variability in processes, and therefore unnecessary costs. On the other hand, Lean focuses on rationalization processes that increase business revenue, reduce costs and help optimize unnecessary activities. Both methodologies are complementary and should be used simultaneously, with the objective of improving both quality of the Ps/Ss offered and customer satisfaction (Salah et al., 2010).

The 6σ methodology was very successful shortly after its launch, due to its new approach strategy (López-Guerrero et al., 2019). This led to its use in different activities in various industries, such as: optimizing the manufacturing flow in the automotive industry (Fadly & Mohd, 2013), improving the quality of integrated circuit design in the electronics industry (Su et al., 2005), reducing acquisition delays, i.e., in the inbound logistics for companies (Das, 2005), etc. This methodology is most useful in the management of projects where there are significant resource constraints.

Breyfogle III (2003) suggested that, in order to improve business performance, companies should consider four dimensions: financial, internal business processes, learning and growth. These dimensions can be tracked using tools, such as the aforementioned BSC, whose monitoring criteria are similar to those established by the 6σ methodology. Snee and Rodenbaugh Jr (2002) identified that the projects to which this methodology is applied should be related to the strategic objective. Goldstein (2001) indicated that these projects should focus on activities that are critical to both quality and financial performance, while Brue and Formisano (2002) considered that the selection of these types of projects should be made taking into account resources and time.

Subsequently, new mechanisms have been proposed to maximize financial results in a company. Some authors, like George et al. (2004), advocated the recognition of the client's opinion together with the business approach focused on the surrounding processes for the selection of projects to which the L6σ methodology should be applied.

As an application of this innovative methodology, Pepper and Spedding (2010) examine the integration of Lean principles into the 6σ methodology as a coherent approach to continuous improvement, providing a conceptual model for their successful integration.

For their part, Psychogios et al. (2012) carried out research on issues related to the application of the L6σ methodology in the telecommunications service industry. They analytically explored the critical success factors involved in the implementation of L6σ. Their work is conceived from a qualitative perspective, which explores the nature of the L6σ application in a service company context and presents case studies from the telecom industry. Similarly, Furterer (2016) proposes the use of the L6σ methodology in service industries, where variables are directly related to changing customer needs.

In an interesting article, Vinodh and Swarnakar (2015) present an application of the L6σ methodology using a hybrid solution, in which the conjunction of decision-making models based on DAMATEL, ANP and TOPSIS are used, while Uluskan (2019) analyses different L6σ tools from a multidimensional perspective.

There are several studies, such as those conducted by Albliwi et al. (2014) and Zhang et al. (2012a), in which a literature review of the application of the L6σ methodology is carried out. Additionally, this methodology has been recently applied in several areas of the economy, such as the public sector (Rodgers et al., 2021), academic and governmental environments (Furterer, 2016), higher education (Cudney et al., 2020), leadership (Laureani & Antony, 2018), business excellence (Corbett, 2011), small scale industries (Muthukumaran et al., 2017), the manufacturing industry (Albliwi et al., 2015), services (Sunder et al., 2018), and telecommunications (Shamsuzzaman et al., 2018), among others.

All these previous works, although based on different approaches, pursue the same objective, which is to improve both efficiency and business performance indicators. Some of them also consider customers' satisfaction, and even their opinion.

1.3. Application of IFSs to decision-making problems

The eXvaluation regarding the criteria considered to select a project (from different alternatives) in which the L6σ methodology is applied could be considered a Fuzzy Multi-Criteria Decision-Making (FMCDM) problem, in which the assessments and opinions of multiple experts can be handled. Several approaches have been published on different aspects of decision-making problems, and there is a significant number of studies on FMCDM (Chien-Chang, 2010; Mardani et al., 2015; Önüt et al., 2009; Patil & Kant, 2014; Wang, Hsueh et al., 2019; Zhang et al., 2016). Other examples of more recent FMCDM approaches are: Simplified Best Worst Method (SBWM) (Amiri et al., 2021), Multi-Attributive Border Approximation Area Comparison (MABAC) (Zhao et al., 2021), Simultaneous Evaluation of Criteria and Alternatives (SECA) (Keshavarz-Ghorabaee et al., 2018), Stepwise Weight Assessment Ratio Analysis (SWARA) II (Keshavarz-Ghorabaee, 2021), MEthod based on the Removal Effects of Criteria (MEREC) (Keshavarz-Ghorabaee et al., 2021), and Evaluation based on Distance from Average Solution (EDAS) (Zindani et al., 2019). However, when making group decisions in a fuzzy environment, individual human opinions often conflict. Therefore, many research works, such as those carried out by Alonso et al. (2009), Boran et al. (2009), Cabrerizo et al. (2009) and Pérez et al. (2010, 2011), have extended the FMCDM problem to a group decision-making process.

In this context, the contributions made using IFSs are also important, as evidenced by the research carried out by many authors (Das et al., 2017; Lu et al., 2021; Nayagam et al., 2011; Rani & Garg, 2017; Sadiq & Tesfamariam, 2009; Vukasovi et al., 2021; Xu, 2007a, 2007b; Zhang et al., 2018). The use of IFSs in the resolution of decision-making problems has had a great impact, due to their great flexibility in representing situations of uncertainty, and they are a widely accepted approach to modelling these problems (Behret, 2014; Das et al., 2017; Ntepe et al., 2013; Pei & Zheng, 2012; Xu & Zhang, 2019; Xu & Zhao, 2016; Xu, 2011a).

Like the L6σ methodology, over the last decade, IFSs have also been applied to various fields or areas, such as: Industrial maintenance management (Ohta et al., 2020), sentiment analysis (Liu et al., 2017), medical diagnosis (Mondal & Pramanik, 2015), medical images (Chaira, 2011), mobile telephone service (Mishra et al., 2019, 2020), cloud computing technology (Büyüközkan et al., 2018), and information technology service outsourcing (Zhang et al., 2012b), to mention a few.

1.4. Treatment of customer non-preferences in the literature

There is a series of studies that use non-preferences to be able to interpret user preferential inclinations with respect to different issues, as shown in Table 1. Despite the approaches included in this table, we can conclude that the use of both preferences and non-preferences expressed by customers regarding their interest in the use of a P/S has not been sufficiently studied. Thus, taking user non-preferences into account in customer management can be as important as considering their preferences (Morozan & Ciacu, 2012).

Table 1. Main features of approaches that use non-preferences

References	Fundamentals	Applications	Non-preference Roles
Aggarwal et al., 2017	Multi Criteria Group Decision Making & IFS	Ranking of on-line travel agencies (OTA) websites	Non-preferences in decision making provided by the decision maker
Ahmad & Juhdi, 2009	Multiple linear regression	Identifying barriers to use travel e-service	Non-preference of a traveler to use travel e-service
Ait Haddadene et al., 2016, 2019	Multi-objective optimization	Home Healthcare: Schedule the visits of caregivers	Non-preference of a client to a caregiver
Arora & Kumari, 2015	Structural equation modeling	Psychological behavior of investors	Determining whether non-preference channels (loss aversion and regret) were found to be mediating variables between self-esteem and stock market participation
Brix & Lauridsen, 2014	Multiple qualitative case study	Improving practical teamwork by enhancing personal and interpersonal learning competencies	Learning non-preferences from team members
Huang, 2017	Recommender System & Latent Dirichlet Allocation (LDA)	Recommending properties to guests on Airbnb	Non-preferences of the guest
Renaud et al., 2003	MCDM & Rough Sets Method (RSM)	Design of chemical processes for pulp-processing	Non-preferences of the chemical experts in decision-making
Son & Kim, 2017	Content-based filtering (CBF), multiattribute network & clustering	Recommending movies	Non-preferences of customers regarding movies
Gündogdu et al., 2021	Picture Fuzzy AHP & Linear Assignment models	Evaluating public transport service quality in Budapest	Hesitancy of the experts in decision-making
Wang, Yang et al., 2019	Bayesian Personalized Ranking (BPR) & Deep Matrix	Recommendations on online social networks	Non-prefereces of the social network users
Xu, 2011b	Intuitionistic fuzzy value, MCDM & Optimization model	Selecting a mobile phone	Decrease in the degree of satisfaction of some alternatives by the decision maker in the interactive decision process
Our proposal	L6σ & IFSs	Design/development of telecom Ps/Ss	Non-preferences of the users regarding the current Ps/Ss or the ones to be developed

Moreover, to the best of our knowledge, there are also no case studies in which IFSs are used to design new Ps/Ss to be launched in a sector as important for economic development as telecommunications. For this reason, we integrate the use of IFSs into our proposal, to be able to contemplate both preferences and non-preferences expressed by the users with respect to the Ps/Ss marketed and/or those that will be developed and launched on the market. In this sense, our proposal is the first of its kind in this field of research.

Once we have reviewed the literature regarding these four fundamental aspects of our proposal, we devote the following section to present the theoretical foundations that are necessary for the implementation of the decision-making model proposed in this article, which is aimed at designing Ps/Ss that best suit customers' tastes and needs, based on both their preferences and non-preferences.

2. Fundamentals used in our proposal

The definitions presented in the following subsections are used by the model we propose to be able to relate two independent sets of fuzzy information that share certain characteristics.

2.1. Intuitionistic Fuzzy Sets

First of all, we need to clearly establish what an IFS is.

Definition 1: *Intuitionistic Fuzzy Set* (IFS), according to Atanassov (1999). Let X be a non-empty set, the IFS A can be defined in X as indicated by Eq. (1):

$$A = \{x, \mu_A(x), \nu_A(x) : x \in X\}, \tag{1}$$

where $\mu_A(x), \nu_A(x) : X \to [0,1]$ respectively defines the degree of membership and non-membership of the elements $x \in X$ regarding the IFS A, which is a subset of X, and where $\forall x \in X, 0 \le \mu_A(x) + \nu_A(x) \le 1$ is fulfilled.

In addition, we have $\pi_A(x) = 1 - \mu_A(x) - \nu_A(x)$, which is called *index of the intuitionistic fuzzy set*, also known as the *hesitation margin* of x in A, so $\pi_A(x)$ is the degree of indetermination of the membership of $x \in X$ regarding the IFS A. Therefore, $\pi_A(x)$ expresses ignorance of whether x belongs to the IFS A or not.

2.2. Relations and operations with IFSs

Atanassov (1999) also defined a series of relations and operations between IFSs, such as those expressed by Eqs (2)–(8), among others.

Equality:

$$A = B \leftrightarrow \mu_A(x) = \mu_B(x) \text{ and } \nu_A(x) = \nu_B(x), \forall x \in X. \tag{2}$$

Inclusion:

$$A \subseteq B \leftrightarrow \mu_A(x) \le \mu_B(x) \text{ and } \nu_A(x) \ge \nu_B(x), \forall x \in X. \tag{3}$$

Complement:

$$A^c = \{x, \nu_A(x), \mu_A(x) : x \in X\}. \tag{4}$$

Union:

$$A \cup B = \left\{x, \max\left(\mu_A\left(x\right), \mu_B\left(x\right)\right), \min\left(\nu_A\left(x\right), \nu_B\left(x\right)\right) : x \in X\right\}. \tag{5}$$

Intersection:

$$A \cap B = \left\{x, \min\left(\mu_A\left(x\right), \mu_B\left(x\right)\right), \max\left(\nu_A\left(x\right), \nu_B\left(x\right)\right) : x \in X\right\}. \tag{6}$$

Addition:

$$A \oplus B = \left\{x, \mu_A\left(x\right) + \mu_B\left(x\right) - \mu_A\left(x\right) \cdot \mu_B\left(x\right), \nu_A\left(x\right) \cdot \nu_B\left(x\right) : x \in X\right\}. \tag{7}$$

Difference:

$$A - B = \left\{x, \min\left(\mu_A\left(x\right), \nu_B\left(x\right)\right), \max\left(\nu_A\left(x\right), \mu_B\left(x\right)\right) : x \in X\right\}. \tag{8}$$

2.3. Intuitionistic fuzzy aggregation and distance operators

Aggregation operators are very useful for determining the overall trend of a group of finite values. According to Wan et al. (2020), there is a wide variety of aggregation operators that are used in IFSs. However, we only present the widely used weighted average operator (Xu, 2007a, 2007b; Zhao et al., 2010), as it is the one we will use in this paper. A definition of this operator is given just below.

Definition 2: *Intuitionistic fuzzy power aggregation operator*, according to Xu (2011a). Let $\alpha_i = \left(\mu_{\alpha_i}, \nu_{\alpha_i}, \pi_{\alpha_i}\right), \forall i \in \left\{1,2,\ldots,n\right\}$, be a collection of intuitionistic fuzzy numbers, and $w = \left(w_1, w_2, \ldots, w_n\right)$ the vector of weights assigned to each α_i, where $w_i \geq 0, \forall i \in \left\{1,2,\ldots,n\right\}$, taking into account that $\sum_{i=1}^{n} w_i = 1$, then it is possible to define the intuitionistic fuzzy power aggregation operator $\mathcal{IFPWA}\left(\alpha_1, \alpha_2, \ldots, \alpha_n\right)$ as expressed by Eq. (9):

$$\mathcal{IFPWA}\left(\alpha_1, \alpha_2, \ldots, \alpha_n\right) = \frac{\left(w_1 \cdot \left(1 + T\left(\alpha_1\right)\right) \cdot \alpha_1\right) \oplus \left(w_2 \cdot \left(1 + T\left(\alpha_2\right)\right) \cdot \alpha_2\right) \oplus \ldots \oplus \left(w_n \cdot \left(1 + T\left(\alpha_n\right)\right) \cdot \alpha_n\right)}{\sum_{i=1}^{n} w_i \cdot \left(1 + T\left(\alpha_i\right)\right)}, \tag{9}$$

where $T\left(\alpha_i\right) = \sum_{\substack{j=1 \\ j \neq i}}^{n} Sup\left(\alpha_i, \alpha_j\right)$ and $Sup\left(\alpha_i, \alpha_j\right)$ is the support for α_i from α_j, which meets the following rules:

(1) $Sup\left(\alpha_i, \alpha_j\right) \in \left[0,1\right]$;

(2) $Sup\left(\alpha_i, \alpha_j\right) = Sup\left(\alpha_j, \alpha_i\right)$;

(3) $Sup\left(\alpha_i, \alpha_j\right) \geq Sup\left(\alpha_s, \alpha_t\right)$, if $d\left(\alpha_i, \alpha_j\right) < d\left(\alpha_s, \alpha_t\right)$, where d is a distance measure, such as the normalized Hamming distance or the normalized Euclidean distance.

According to Xu and Yager (2008), among others, in problems where vectors have to be compared, it is necessary to measure the distance between them. There are different definitions on distance measurement (Garg, 2017; Rani & Garg, 2017; Singh & Garg, 2017; Szmidt, 2014; Zhang et al., 2020); however, one of the most widely used is the Euclidean distance. In our case, we have used the normalized Euclidean distance, which is defined just below.

Definition 3: *Normalized Euclidean distance*, according to Szmidt (2014). Let A and B be two IFSs that have the same number of elements (n), then the normalized Euclidean distance $d^e_{\mathcal{IFS}}(A,B)$ between these two sets is defined as expressed by Eq. (10):

$$d^e_{\mathcal{IFS}}(A,B)=\left(\frac{1}{2n}\sum_{i=1}^{n}\left[\left(\mu_A(x_i)-\mu_B(x_i)\right)^2+\left(\nu_A(x_i)-\nu_B(x_i)\right)^2+\left(\pi_A(x_i)-\pi_B(x_i)\right)^2\right)\right]\right)^{\frac{1}{2}}. \quad (10)$$

Once we have presented the necessary support to perform both the basic operations with IFSs and the process of aggregating information expressed by different people, as well as an adequate mechanism to calculate distance between vectors, we will proceed to present our proposal in the following section.

3. Proposal of a new decision-making model based on L6σ and IFSs

In order to adequately explain the decision-making model we propose, in the first subsection, we will give an overview of our proposal, indicating in which specific phases we will use the fundamentals on which it is based, while we will describe in detail each of the steps included in our approach in the second subsection.

3.1. Overview of our proposal

The purpose of the approach we propose is to be able to design Ps/Ss according to both preferences and non-preferences expressed by the customers of a given company. To do so, we use the L6σ methodology supported by IFSs. With this, we intend to achieve a twofold objective: to include the process optimization principles described in L6σ, which help to improve both the procedure efficiency and the financial and resource performance in the industry, and to be able to model customer preferences and non-preferences using IFSs, to better interpret what each customer needs through their responses to a survey. All this is aimed at generating new Ps/Ss that are better adapted to the needs of customers, based on what they have expressed by filling in a survey form.

Figure 2 schematically represents the proposed decision-making model. The top left box indicates that there are two groups of people providing input data to the model: a group of experts and customers. Although we will detail what data each group provides in the following subsection, both groups will indicate both their preferences and their non-preferences with respect to the information requested. The following box (located at the top center of the figure) summarizes the processing that is carried out from the input data provided: a series of Ps/Ss are defined, using both the preferences and non-preferences expressed by both groups, and finally the P/S most suitable to the tastes and needs of each client is obtained. In order to determine the degree of satisfaction of each client with the P/S that has been recommended to hire, after a certain time of the date on which it was offered, it would be necessary to carry out a tracking and monitoring process. The information collected in said process will be represented visually through dashboards, so that they serve as support to the managers of the company for an adequate decision making in order to design new Ps/Ss. This is what is indicated in the upper right box.

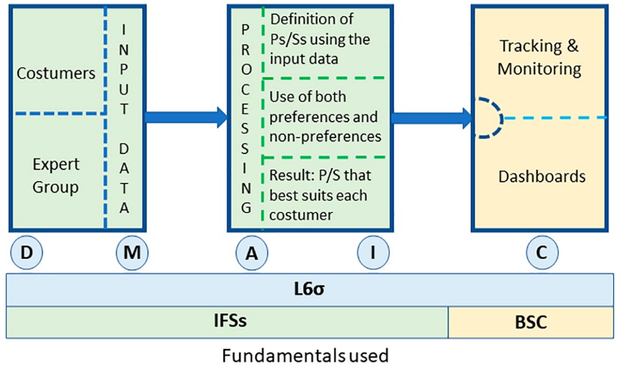

Figure 2. Schematic diagram of our proposal

The bottom of Figure 2 shows the methodological and technical foundations we use in our proposal. Thus, as can be seen, the L6σ methodology (and, more specifically, the five phases established by the DMAIC structure used in 6σ) is applied throughout the entire process, while the IFSs would only be applied in the first 4 of those phases, and the BSC tools only in the last of them.

In summary, we can say that, to achieve our purpose, we have developed the incorporation of IFSs into the L6σ methodology. This allows us to apply the phases established in the aforementioned DMAIC approach to the design of Ps/Ss that best suit to the tastes and needs of each client, based on not only the preferences but also the non-preferences expressed by each of them.

3.2. Step-by-step explanation of the proposed model

Figure 3 represents our proposal in more detail by means of a flow chart, where each block has been placed in a specific column and row depending respectively on the phase where it is executed and the type of operation it represents. Thus, we can see five columns corresponding to the different phases considered in our approach, which are inspired by the DMAIC structure. We therefore refer to these phases as *Define*, *Measure*, *Analyse*, *Improve* and *Control*. Within each of these phases, we have defined a series of steps or processes (represented with coloured elements or blocks). These steps or processes may correspond to *input*, *processing* or *output* operations, so they are placed in the corresponding row of the diagram.

The first step to be performed in our proposal is included in the first phase, called ***Define***, and corresponds to an *input* operation. It frames and defines the specific characteristics of the project in question, among which we can mention: the criteria considered for evaluating the Ps/Ss, the list of Ps/Ss that make up the different alternatives to be evaluated, the specific form to be filled in by the clients participating in the study, the aggregate opinions expressed by the experts, etc. All this information should be provided by the expert group. They must define the survey form according to specific requirements in order to be able to evaluate the degree of belonging and non-belonging of each client's opinion (i.e., their preference and non-preference) with respect to each of the questions asked. Therefore, this step defines and inputs all the variables and elements involved in the assessment or analysis procedure to be implemented in the following phases.

The second step, which is performed in the ***Measure*** phase and corresponds to another *input* operation, is responsible for providing the customer group participating in the study and their answers to the questions posed in the survey conducted, which was defined in the previous phase. Thus, the information expressed by clients when completing the survey will assign values to the previously defined variables, in order to identify each client's tastes and needs.

The following steps are *processing* operations and constitute the core of the proposal presented, where all the information collected in the two steps previously explained is integrated, in order to make way for the rest of the phases and the different processes that will take place in them. As indicated, this information includes the list of proposed Ps/Ss, the criteria with which these Ps/Ss will be evaluated, the experts' aggregate opinion on them, the form that clients must fill in, the group of customers participating in the survey and the responses given by these customers when filling in the survey form.

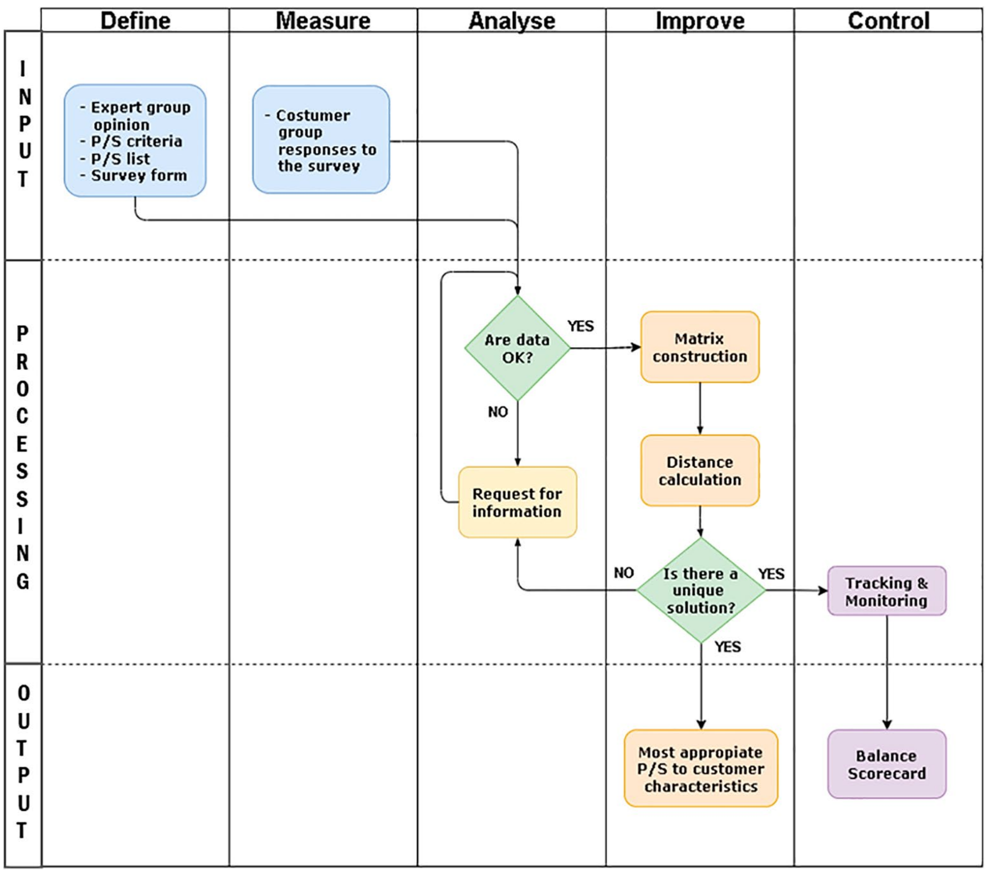

Figure 3. Diagram representing the proposed decision-making model, which integrates L6σ and IFSs

In the ***Analyse*** phase, the first step (represented by the first diamond in Figure 3) validates the data entered and makes decisions based on the checking performed. Therefore, incomplete data will need to be completed or deleted. As can be seen in Figure 3, the information classified as incomplete is sent to the next step, i.e., the procedure called *Request for information*, which is executed until all the data are OK.

In the ***Improve*** phase, customer opinion matrices are first built (one for each customer) and all the information is represented by IFSs. Then, the distance between what each of the clients expressed in the survey conducted and the characteristics of the different Ps/Ss proposed (result of the assessment carried out by the group of experts) is calculated, in order to determine the shortest distance between the needs of each customer and each of the Ps/Ss considered. In the final part of this phase, we find a decision element (represented by the second diamond in Figure 3) that allows us to find out if the responses expressed by each customer correspond to a single P/S. If the preferences and non-preferences expressed by the customer correspond to more than one P/S, the algorithm returns to the *Request for information* procedure in order to adequately clarify the existing similarities and thus ensure that the result is unique in the next iteration. In the case of a single solution, an *output* operation is generated consisting of the list of clients for whom it has been possible to determine the P/S that best suits their needs, so that the most suitable P/S is identified for each of them.

Finally, the ***Control*** phase is reached, which is designed to ensure that the results obtained reflect the real needs of the clients who participated in the process (by responding to the questions posed in the survey conducted). This last phase requires a monitoring process over time (carried out by the after-sales service) in order to check if clients are really satisfied with the P/S recommended to each of them. If so, this will bring a number of benefits to the company, such as increased revenue, improved corporate image, attracting more clients, increasing the customer retention rate, etc. This phase is carried out by using follow-up and monitoring over time tools to see how certain variables (those that company managers wish to monitor) evolve. As a result, these tools will produce as *output* dashboards that follow the BSC philosophy, which will show which values the variables considered are obtaining at each point in time by means of intuitive graphs. This will undoubtedly help company managers make better decisions with respect to the Ps/Ss for which the study was conducted, and provides important information to be taken into account when desining new Ps/Ss.

4. Application to a case study in the telecom sector

The telecommunications sector is of great importance in the contemporary world, so much so that the providers of these services face intense competition. Hence the importance of developing mechanisms that help improve user satisfaction in order to offer them commercial plans tailored to their needs, and thus improve customer retention. At the same time, the aim is to avoid dissatisfaction that could lead clients to cancel their contracted services and even migrate to other operators. This would be reflected in the company's loss of income.

In this section, we will show details of how to apply the proposed decision-making model, which is based on L6σ and IFSs, to a telecommunications operator, in order to determine the level of satisfaction of its clients with respect to the P/S packages offered by said operator. To apply our proposal to a case study we must execute the processes or operations respresented in Figure 3 step-by-step and in the order shown in the flow diagram depicted therein, as we have explained in Subsection 3.2.

This is the case study we have chosen: A telecom company is interested in increasing the satisfaction of its users with respect to its Ps/Ss. By doing so, it hopes to increase its revenue, lower its customer service costs, and improve its brand and corporate image. In this regard, its managers have developed a strategy focused on making a projection of possible users for the new commercial P/S packages that they plan to launch on the market next semester. To achieve the goal of offering each customer the commercial plan that best suits their needs, the company wants to test with real customers to determine that plan based on the answers each user gives to a survey.

For this case study, a group of experts has been chosen to assess or define the composition of each plan in terms of the aspects to be considered regarding the Ps/Ss contained in them, that is, the evaluation criteria. In addition, the answers given by a group of clients to the set of questions included in a survey form are used to determine the telecommunication service needs of each of these clients.

In this case study, the set of P/S packages to be launched or commercialized, denoted as $P = \{p_1, \ldots, p_n\}$, will contain 4 specific packages, called *All in One*, *Advantage*, *Forza Plus* and *Pro Mundi*. Each of these packages is made up of a series of Ps/Ss that will be evaluated using the same set of criteria, $C = \{c_1, \ldots, c_m\}$, which are the 5 criteria shown in Table 2. The definitions of the criteria chosen for this particular case study are as follows:

- c_1 is the number of minutes included in the fixed telephone service commercial plan, which includes minutes for calls to the same network (on-net), to other fixed operators (off-net), to the international call service, and to mobile service operators.
- c_2 is the number of minutes and SMSs included in the advanced mobile service commercial plan, which consists of minutes for calls within the same network (on-net), to other mobile operators (off-net), to the international call service, and to fixed service operators.
- c_3 is the satellite television service, which refers to both the channels included in the commercial plan and the distribution of SD (Standard Definition) and HD (High Definition) channels.
- c_4 refers to the fixed internet service commercial plan with respect to the included browsing speed (Mb/s).
- c_5 refers to the mobile data service, as well as the number of Gb included in it and its distribution considering different criteria (social networks, free browsing, etc.).

Table 2. Criteria to be used to assess the different commercial plans or P/S packages

Criterion	Telecom service involved	Service feature to be assessed
c_1	Fixed Telephone Service	Number of landline minutes
c_2	Advanced Mobile Service	Number of mobile phone minutes (on net/off net)
c_3	Direct to Home (Satellite TV)	Number of satellite TV channels (HD and SD)
c_4	Fixed Internet (Broadband)	Fixed broadband
c_5	Mobile Internet (Mobile Data)	Mobile broadband

Therefore, for this specific case study, a two-dimensional matrix must be formed that contains: the set of the 4 new commercial packages to be launched $\left(P=\left\{p_1,\ldots,p_4\right\}\right)$, placed in its rows; and the set of evaluation criteria, placed in its columns, which will be made up of the specific features to be assessed in the 5 telecom services shown in Table 2 $\left(C=\left\{c_1,\ldots,c_5\right\}\right)$. These services are those that make up each commercial package or plan that the telecom operator wants to offer.

Each of the elements of said two-dimensional matrix has been assessed by a group of 3 experts from the company's commercial area, denoted as $E=\left\{e_1,\ldots,e_3\right\}$. The use of IFSs is proposed for said assessment, taking into account that each of the experts in E has to express the degree of both belonging and non-belonging of each element from P according to each of the criteria included in C. This means that participants (both experts and clients) will have to give more thought to their responses, considering the relationship of each of these two components in each of the responses expressed. Subsequently, the degree of hesitation will be automatically calculated from the responses expressed and incorporated into the aforementioned matrix.

The structure of the two-dimensional $\left(n\times m\right)$ matrix MVP is shown in Eq. (11). It contains the final aggregate valuations expressed by the group of experts $E=\left\{e_1,\ldots,e_3\right\}$ for each of the commercial packages or plans considered in the study, according to the different features of the Ps/Ss that comprise them. In other words, the matrix $MVP=\left\{V_{ij}\right\}$, $\forall i\in\left\{1,\ldots,n\right\}$, $\forall j\in\left\{1,\ldots,m\right\}$, where n is the number of commercial plans considered $\left(P=\left\{p_1,\ldots,p_n\right\}\right)$, and m is the number of evaluation criteria $\left(C=\left\{c_1,\ldots,c_m\right\}\right)$, shows the aggregate assessments (from all the experts) for each pair (package, criteria). To calculate each of the values in this matrix, the aggregation operator established in Definition 2 has been used.

$$MVP=\begin{bmatrix} V_{11} & \cdots & V_{1m} \\ \vdots & \ddots & \vdots \\ V_{n1} & \cdots & V_{nm} \end{bmatrix}. \tag{11}$$

Eq. (12) shows the matrix containing the aggregate valuations expressed by the expert group for each plan or package considered according to the features of the Ps/Ss they contain.

$$MVP=\begin{bmatrix} (0.8,0.1) & (0.7,0.2) & (0.9,0.0) & (0.5,0.3) & (0.8,0.1) \\ (0.7,0.2) & (0.8,0.1) & (0.7,0.1) & (0.5,0.3) & (0.9,0.0) \\ (0.9,0.0) & (0.8,0.1) & (0.9,0.1) & (0.6,0.4) & (0.8,0.1) \\ (0.7,0.2) & (0.6,0.3) & (0.8,0.1) & (0.5,0.3) & (0.7,0.2) \end{bmatrix}. \tag{12}$$

From the matrix shown in Eq. (12), and applying what is expressed in Definition 1, it is possible to automatically construct the matrix presented in Eq. (13), where each of its elements is a triplet formed by the values corresponding to μ_A, ν_A and π_A.

$$MVP=\begin{bmatrix} (0.8,0.1,0.1) & (0.7,0.2,0.1) & (0.9,0.0,0.1) & (0.5,0.3,0.2) & (0.8,0.1,0.1) \\ (0.7,0.2,0.1) & (0.8,0.1,0.1) & (0.7,0.1,0.2) & (0.5,0.3,0.2) & (0.9,0.0,0.1) \\ (0.9,0.0,0.1) & (0.8,0.1,0.1) & (0.9,0.1,0.0) & (0.6,0.4,0.0) & (0.8,0.1,0.1) \\ (0.7,0.2,0.1) & (0.6,0.3,0.1) & (0.8,0.1,0.1) & (0.5,0.3,0.2) & (0.7,0.2,0.1) \end{bmatrix}. \tag{13}$$

All the information required to be able to build the matrix shown in Eq. (13) is the result of the first step to be carried out, which is located in the *Define* phase, as shown in Figure 3.

The next step to be taken is in the *Measure* phase of our decision-making model, where the opinions of each client regarding the Ps/Ss that make up each new package that the company wants to launch are collected. For this purpose, customers will express their opinion or degree of interest in each proposed plan or package, indicating their degree of belonging or non-belonging in relation to the criteria or aspects to be assessed (in this case, features of the Ps/Ss included in each plan). To achieve this objective, a survey elaborated on the principles given by Marasini et al. (2016) has been conducted, so that clients can express their opinion regarding the features that make up each of the proposed P/S packages or plans.

To appropriately collect the opinions of the set of clients or users $U = \left\{u_1,\dots,u_p\right\}$ regarding the set of evaluation criteria $C = \left\{c_1,\dots,c_m\right\}$, a new two-dimensional $\left(p \times m\right)$ matrix, called *MVC*, must be created. This matrix will be made up of the valuations of the features considered relevant to the commercial plans offered by the company (i.e., the ones considered in this study), expressed by a group of users or customers selected according to their profile and/or to their history of services previously contracted. This step is carried out in the *Measure* phase, as shown in Figure 3.

Therefore, information on customer responses will be contained in the matrix $MVC = \left\{V_{kj}\right\}, \forall k \in \left\{1,\dots,p\right\}, \forall j \in \left\{1,\dots,m\right\}$, where p is the total number of participating clients and m is the number of commercial features valued. The structure of this matrix, which contains the individual responses or ratings given by each of the users involved in the process for each of the features assessed, is shown in Eq. (14).

$$MVC = \begin{bmatrix} V_{11} & \cdots & V_{1m} \\ \vdots & \ddots & \vdots \\ V_{p1} & \cdots & V_{pm} \end{bmatrix}. \tag{14}$$

To provide this information, the company's marketing area contacted a group of customers or users $U = \left\{u_1,\dots,u_p\right\}$ that were using the operator's services to assess the set of features shown in Table 2 $\left(C = \left\{c_1,\dots,c_m\right\}\right)$, which will form part of the commercial packages or plans to be launched. From these evaluations, the actual profile of potential customers can be determined in relation to the new commercial plans to be marketed.

Therefore, the information initially required is provided by clients through a survey, using a model form like the one described by Marasini et al. (2016), through which it is possible to determine the degree of both belonging and non-belonging regarding each criterion to be assessed. Subsequently, the hesitation margin is automatically determined based on the two values previously established for each criterion by each participating user. In this way, each client's assessments on the different features of the Ps/Ss contained in the commercial packages to be launched are obtained.

As an example, the valuations expressed by the first 4 clients of the selected group (2135 users in total) for each of the (5) features of the Ps/Ss included in the packages or plans to be commercialized are shown in Eq. (15).

$$MVC = \begin{bmatrix} (0.6,0.2) & (0.6,0.2) & (0.8,0.0) & (0.5,0.2) & (0.7,0.3) \\ (0.8,0.1) & (0.7,0.1) & (0.8,0.1) & (0.6,0.4) & (0.8,0.2) \\ (0.7,0.2) & (0.7,0.2) & (0.8,0.0) & (0.5,0.2) & (0.8,0.1) \\ (0.7,0.2) & (0.7,0.2) & (0.7,0.2) & (0.5,0.3) & (0.8,0.0) \end{bmatrix}. \tag{15}$$

As mentioned above, from the matrix shown in Eq. (15) and applying what is expressed in Definition 1, it is possible to automatically construct the matrix shown in Eq. (16), where each of its elements is a triplet, whose values correspond to to μ_A, ν_A and π_A.

$$MVC = \begin{bmatrix} (0.6,0.2,0.2) & (0.6,0.2,0.2) & (0.8,0.0,0.2) & (0.5,0.2,0.3) & (0.7,0.3,0.0) \\ (0.8,0.1,0.1) & (0.7,0.1,0.2) & (0.8,0.1,0.1) & (0.6,0.4,0.0) & (0.8,0.2,0.0) \\ (0.7,0.2,0.1) & (0.7,0.2,0.1) & (0.8,0.0,0.2) & (0.5,0.2,0.3) & (0.8,0.1,0.1) \\ (0.7,0.2,0.1) & (0.7,0.2,0.1) & (0.7,0.2,0.1) & (0.5,0.3,0.2) & (0.8,0.0,0.2) \end{bmatrix}. \quad (16)$$

As shown in Figure 3, the next step to be performed is found in the *Analyse* phase of our proposal, which is responsible for checking that all the data provided in the previous phases (i.e., *Define* and *Measure*) are consistent and complete. Once all the data are OK, the next step, which is in the *Improve* phase, can be executed. This step consists of constructing the *MVP* and *MVC* matrices, whose structures are shown respectively in Eqs (11) and (14). To do so, what was expressed by the experts in the *Define* phase and the users' opinions on the features of the Ps/Ss that make up each package to be marketed (given in the *Measure* phase) must be used respectively.

Once both matrices have been built, and according to Figure 3, the next step consist of calculating the distance between the responses provided by each client with respect to the reference values established by the group of experts for each of the features assessed (about the Ps/Ss included in each commercial package or plan), by applying Definition 3. The distance between the aggregated assessments of each package or plan made by the experts and the opinions of each customer with respect to the (5, in this case) criteria considered, denoted as $d^e_{\mathcal{IFS}_{i,k}}(MVP, MVC), \forall i \in \{1,\ldots,n\}, \forall k \in \{1,\ldots,p\}$, expresses the distance between the telecommunication P/S needs of each customer or user with respect to the composition of each package or plan to be marketed by the company.

As an example, Eq. (17) indicates how to calculate the (normalized Euclidean) distance between the values in the first row of the *MVP* matrix (corresponding to assessment on the *All in One* package made by the experts, and shown in Eq. (13)) and the first row of the *MVC* matrix (corresponding to the valuations of user u_1 that are shown in Eq. (16)).

$$\begin{aligned} & d^e_{\mathcal{IFS}_{1,1}}(MVP, MVC) = \\ & \left(\frac{1}{2\cdot 5}\left((0.8-0.6)^2+(0.1-0.2)^2+(0.1-0.2)^2\right)+\right. \\ & \left((0.7-0.6)^2+(0.2-0.2)^2+(0.1-0.2)^2\right)+ \\ & \left((0.9-0.8)^2+(0.0-0.0)^2+(0.1-0.2)^2\right)+ \\ & \left((0.5-0.5)^2+(0.3-0.2)^2+(0.2-0.3)^2\right)+ \\ & \left.\left((0.8-0.7)^2+(0.1-0.3)^2+(0.1-0.0)^2\right)\right)^{\frac{1}{2}} = \\ & \sqrt{\left(\frac{1}{10}(0.180)\right)} = 0.1341. \end{aligned} \quad (17)$$

Therefore, the value obtained corresponds to the distance between the answers expressed by customer u_1 with respect to the features corresponding to the *All in One* commercial plan, as determined by the assessment made by the group of experts. This value and those corresponding to the remaining distances between the different rows of the *MVP* and *MVC* matrices are shown in Table 3 (given as an example for the first four users only). The minimum distance of each row, which determines the commercial plan or package closest to the needs of the corresponding customer, has been highlighted in bold.

Table 3. Distances between what was expressed by the first four clients of the selected group with respect to the aggregate valuations of the experts on the different commercial plans or packages considered, ordered from the most complete plan (left) to the most basic plan (right)

User \ Plan	Advantage	All in One	Forza Plus	Pro Mundi
u_1	0.2145	0.1341	0.1612	**0.1000**
u_2	**0.0894**	0.1095	0.1342	0.1265
u_3	0.1643	**0.0707**	0.0949	0.0837
u_4	0.1549	0.1095	**0.0775**	0.1000

Therefore, the calculation of the distance between each of the *MVP* matrix rows with respect to each of the *MVC* matrix rows must be carried out prior to obtaining the final results. As shown in Figure 3, the next step is checking that a single option (commercial plan, in this case) has been selected for each user. If so, an output can be generated, which completes the *Improve* phase. With the output generated, which consists of a list of the commercial plan best suited to the needs of each customer, the telecommunications service operator has an important source of information that will enable it to draw the appropriate business conclusions. Thus, in this specific case study, and according to Table 3, which shows the result of applying the proposed decision-making model to the valuations provided by the first four customers (included in the *MVC* matrix) and by the experts (aggregated in the *MVP* matrix) on the features of the telecom Ps/Ss included in the different commercial packages to be launched, we can draw the following conclusions:

- The features included in the *Pro Mundi* commercial plan are those that most closely match user u_1's needs.
- The *Advantage* package features are more tailored to client u_2's needs.
- The characteristics established in the *All in One* plan are best suited to customer u_3's needs.
- The special features set out in the *Forza Plus* package are more appropriate to client u_4's needs.

Figure 4 shows this information for the first 128 (out of 2135) users participating in the case study conducted (in ascending order, according to the number assigned to each customer). It indicates the most appropriate commercial plan for each customer, based on the lowest value obtained in the corresponding distance measurements calculated for the corresponding user with respect to each of the commercial plans considered.

What is shown in Figure 4 has been obtained automatically by running the decision-making model that we have implemented, using the SPSS Modeler® software, to apply our proposal to solve the problem addressed in our case study. In Figure 5, which presents the implementation of the model developed in SPSS Modeler® following the approach described

Customer	Commercial Plan	Customer	Commercial Plan	Customer	Commercial Plan	Customer	Commercial Plan
U001	Pro Mundi	U033	Forza Plus	U065	Pro Mundi	U097	Forza Plus
U002	Advantage	U034	All in one	U066	Advantage	U098	All in one
U003	All in one	U035	Pro Mundi	U067	All in one	U099	Pro Mundi
U004	Forza Plus	U036	Advantage	U068	Forza Plus	U100	Advantage
U005	Forza Plus	U037	Pro Mundi	U069	Forza Plus	U101	Pro Mundi
U006	Advantage	U038	Pro Mundi	U070	Advantage	U102	Pro Mundi
U007	Forza Plus	U039	Advantage	U071	Forza Plus	U103	Advantage
U008	Pro Mundi	U040	All in one	U072	Pro Mundi	U104	All in one
U009	Forza Plus	U041	Pro Mundi	U073	Forza Plus	U105	Pro Mundi
U010	All in one	U042	Advantage	U074	All in one	U106	Advantage
U011	Pro Mundi	U043	All in one	U075	Pro Mundi	U107	All in one
U012	All in one	U044	Forza Plus	U076	All in one	U108	Forza Plus
U013	Pro Mundi	U045	Forza Plus	U077	Pro Mundi	U109	Forza Plus
U014	Pro Mundi	U046	Advantage	U078	Pro Mundi	U110	Advantage
U015	Advantage	U047	Forza Plus	U079	Advantage	U111	Forza Plus
U016	All in one	U048	All in one	U080	All in one	U112	All in one
U017	Pro Mundi	U049	Pro Mundi	U081	Pro Mundi	U113	Pro Mundi
U018	Advantage	U050	Advantage	U082	Advantage	U114	Advantage
U019	All in one	U051	All in one	U083	All in one	U115	All in one
U020	Forza Plus	U052	Forza Plus	U084	Forza Plus	U116	Forza Plus
U021	Forza Plus	U053	Forza Plus	U085	Forza Plus	U117	Forza Plus
U022	Advantage	U054	Advantage	U086	Advantage	U118	Advantage
U023	Forza Plus	U055	Forza Plus	U087	Forza Plus	U119	Forza Plus
U024	Advantage	U056	Advantage	U088	Advantage	U120	Advantage
U025	Forza Plus	U057	Pro Mundi	U089	Forza Plus	U121	Pro Mundi
U026	All in one	U058	Forza Plus	U090	All in one	U122	Forza Plus
U027	Pro Mundi	U059	All in one	U091	Pro Mundi	U123	All in one
U028	Advantage	U060	Pro Mundi	U092	Advantage	U124	Pro Mundi
U029	Pro Mundi	U061	All in one	U093	Pro Mundi	U125	All in one
U030	Pro Mundi	U062	Pro Mundi	U094	Pro Mundi	U126	Pro Mundi
U031	Advantage	U063	Pro Mundi	U095	Advantage	U127	All in one
U032	All in one	U064	Advantage	U096	All in one	U128	Pro Mundi

Figure 4. Screenshots of the table containing the results directly obtained from the implemented model for the 128 first users participating in the study

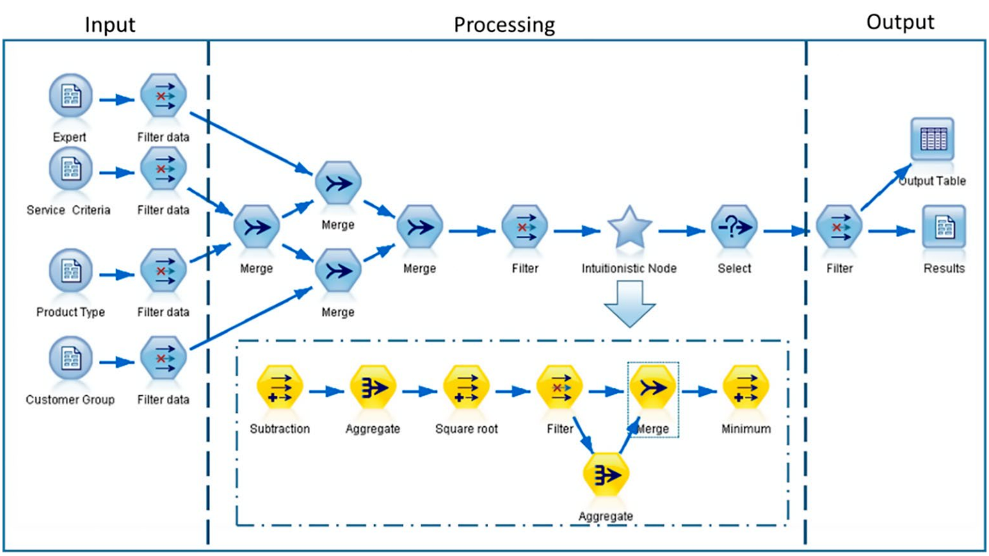

Figure 5. Model implemented in the SPSS Modeler® tool to solve the problem or case study presented

above, we can see the components corresponding to the *input*, *processing* and *output* operations (separated by the vertical dashed lines). The contents of the fuzzy intuitionistic module or subroutine, represented by a star, are also detailed (within the dashed rectangle).

Some time after the commercial launch of the aforementioned packages, the telecom company's After-Sales Department (or whoever carries out these functions) would be in charge of the *Control* phase, according to the diagram shown in Figure 3. The aim of this last phase is to monitor and follow up on the users who have contracted each of the new commercial plans, in order to evaluate their degree of satisfaction and check whether the plan they have contracted really covers their needs or not. The information obtained in the *Tracking* & *Monitoring* process will be presented to the company managers in a visual and intuitive way through dashboards built following the BSC philosophy.

5. Comparative analysis of the results obtained with and without non-preferences

This section aims to show the importance of considering the non-preferences expressed by users, comparing our proposal with another model in which these are not taken into account. To this end, the answers collected in a survey on the P/S packages offered by a given telecommunications company, in which the 2135 participating users expressed both their preferences and non-preferences with respect to each of the Ps/Ss included in those packages, have been analyzed using two models: the one proposed in this paper and another model in which the non-preferences expressed in the answers given by users are not taken into account. Figure 6 graphically represents how both models distribute the 2135 surveyed clients among the different P/S package proposals to be launched by the telecommunications operator.

As can be checked by looking at the blue columns in Figure 6, our model determines that the *Pro Mundi* package would a priori have the largest number of users interested in it, although it also indicates that all packages would have a target audience with a very similar number of customers. Based on these results, the company will probably decide to launch all the proposed commercial packages. If any of the packages were of interest to only a very small number of users, the company would probably decide not to launch such a commercial plan, as it would be of virtually no interest to its customers.

Comparing the results obtained by both models, it was found that the package recommended to the user in question coincided in 48% of the cases (1028 out of a total of 2135). From the remaining 52% of the cases where the result differs (1107 cases), it was found that the model that does not take non-preferences into account suggests a package that exceeds the users' expectations in 12.74% of the cases, while it recommends a package that is slightly below their expectations in 52.84% of the cases, and well below them for the remaining 34.42% of the users.

Therefore, for a significant percentage (52%) of the cases, it is not possible to recommend to users the P/S package that most closely matches their needs. This means that, on the one hand, user dissatisfaction with the Ps/Ss received is favored and, on the other hand, an inadequate distribution of the company's resources is made.

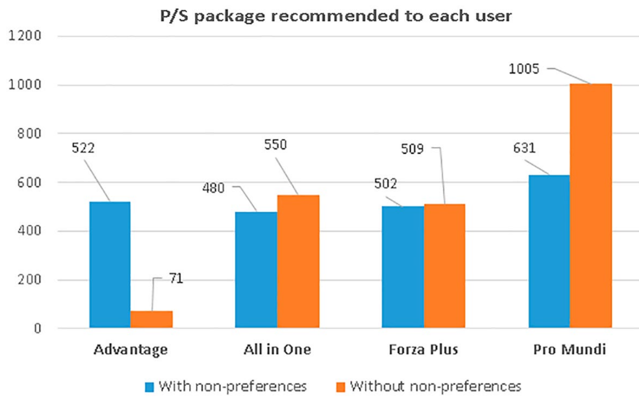

Figure 6. Distribution of the number of users according to the commercial plan or package of Ps/Ss recommended to them by the two models considered in the comparative study. Commercial packages are ordered from the most complete and expensive plan (left) to the most basic and cheapest (right)

Consequently, we think that it is necessary to take into account the non-preferences expressed by users, as they significantly help to establish the users' real needs and, therefore, to make an optimal distribution of resources.

It should also be noted that, comparing the two models in relation to the amount of revenue a company could generate if each user contracted the package recommended by each method considered, the model we propose, in addition to recommending a P/S package that is better adjusted to the needs of each user, would mean generating more revenue for the company than the model that does not take the non-preferences expressed by users into account, as can be seen in Table 4. The values shown in its last two columns have been obtained by multiplying the corresponding commercial plan fee by the number of users (shown in Figure 6) to whom said commercial plan would be recommended, according to each of the two models used in this comparative analysis.

Table 4. Impact on company revenue according to the commercial plan or P/S package recommended to the users participating in the case study for each model

Commercial plan	Commercial plan fee	With non-preferences	Without non-preferences
Advantage	55.00 USD	28,710.00 USD	3,905.00 USD
All in One	45.00 USD	21,600.00 USD	24,750.00 USD
Forza Plus	35.00 USD	17,570.00 USD	17,815.00 USD
Pro Mundi	25.00 USD	15,775.00 USD	25,125.00 USD
Total		83,655.00 USD	71,595.00 USD

Conclusions and future work

A novel decision-making model, which combines the L6σ methodology with IFSs, has been presented for the design of new Ps/Ss taking customer needs into account. Although L6σ has been used in the past for the design of Ps/Ss based on customer needs, information on these needs has always been collected as the preferences expressed by each customer with respect to the criteria considered. In our proposal, we collect not only these preferences, but also the non-preferences that clients might have with respect to such criteria. Therefore, IFSs have played a key role in assembling both components and modeling them in our proposal.

This model has been used to identify customers or users who are potentially interested in the commercial plans (i.e., P/S packages) that a telecom company wants to launch. To do so, a group of experts had to assess in advance to what extent each of the commercial plans to be designed/launched meets a series of characteristics. Then, a series of customers, selected according to their profile or contracting history, also assessed to what extent it is important to them that a given telecom commercial plan has certain features (the same as those assessed by the group of experts).

Without a doubt, the ability of a company to be able to determine the needs of each of its customers and offer them the commercial plan that best suits those needs would have a significant effect on a company's sales efficiency (revenue), as well as on the decrease in the number of customer defections (churn) and on its positioning in a competitive environment (market share). However, it is a delicate decision-making problem that requires an appropriate support mechanism.

To address this problem, our proposal applies the L6σ methodology to optimize processes and improve customer satisfaction, in addition to using IFSs to collect both preferences and non-preferences on certain P/S features through the assessments made by two groups (experts and selected customers). The main underlying idea is calculating the normalized Euclidean distance between the ratings provided by each user (regarding a set of features on the Ps/Ss contained in the proposed commercial plans) with respect to the aggregated ratings expressed by the group of experts (concerning the same characteristics) on each of the plans to be marketed. Thus, it is possible to determine in a fairly precise way which commercial package would best suit the needs of each client.

Consequently, we think our proposal could be of great use and importance, since it provides the company with a support tool for decision making based on precise information provided by the clients themselves. This will enable the telecom company to determine much more accurately and correctly which commercial plans to launch and to which type of clients to offer each of them.

As for the limitations of our proposal, its application would entail carrying out a series of additional actions, such as the preparation of the appropriate questions to be included in the survey form, so that they are easily understood by all users and serve to obtain their preferences and needs with respect to the Ps/Ss considered. Users could even be offered prior training to respond appropriately to the survey (indicating both their preferences and non-preferences).

As future work, we plan to conduct a study similar to the one presented here, but with a linguistic intuitionistic approach so as to facilitate the assessment carried out by experts and clients concerning the different characteristics of the Ps/Ss considered. Therefore, this future proposal would be based on the principle that the human form of communication par excellence is based on natural language. It would also be interesting to explore the possibility of proposing an approach like the one proposed in this paper using some more recent MCDM method, such as SBWM, MABAC, SECA, SWARA II, MEREC, and/or EDAS.

Funding

This work was supported by the Spanish Ministry of Science and Innovation (State Research Agency) under Grants PID2019-103880RB-I00 and PID2019-109644RB-I00; and Junta de Andalucía (Andalusian Regional Government) under Grant PY20_00673.

Author contributions

ACL, MJH and RAC conceived the study and were responsible for the design and development of the methodology as well as its validation through its application to the case study. ACL was responsible for data collection, model implementation and result analysis. ACL also wrote the first draft of the article, while MJH was in charge of reviewing, editing and refining the successive versions of the manuscript. EHV was responsible for the supervision and funding acquisition.

Disclosure statement

Authors declare that they have no competing financial, professional, or personal interests from other parties that may have biased either their research or the article submitted.

References

Aggarwal, A. G., Sharma, H., & Tandon, A. (2017). An intuitionistic approach for ranking OTA websites under multi criteria group decision making framework. In *International Conference Innovation Technology Knowledge* (pp. 21–27). https://doi.org/10.15439/2017KM36

Ahmad, S. N. B., & Juhdi, N. (2009). Barriers to preference of using travel e-service among Internet users. *Journal of Tourism*, *10*(1), 1–16.

Ait Haddadene, S. R., Labadie, N., & Prodhon, C. (2016). A GRASP × ILS for the vehicle routing problem with time windows, synchronization and precedence constraints. *Expert Systems with Applications*, *66*, 274–294. https://doi.org/10.1016/j.eswa.2016.09.002

Ait Haddadene, S. R., Labadie, N., & Prodhon, C. (2019). Bicriteria vehicle routing problem with preferences and timing constraints in home health care services. *Algorithms*, *12*(8), 152. https://doi.org/10.3390/a12080152

Albliwi, S. A., Antony, J., & Lim, S. A. H. (2015). A systematic review of Lean Six Sigma for the manufacturing industry. *Business Process Management Journal*, *21*(3), 665–691. https://doi.org/10.1108/BPMJ-03-2014-0019

Albliwi, S., Antony, J., Abdul Halim Lim, S., & van der Wiele, T. (2014). Critical failure factors of Lean Six Sigma: A systematic literature review. *International Journal of Quality & Reliability Management*, *31*(9), 1012–1030. https://doi.org/10.1108/IJQRM-09-2013-0147

Alonso, S., Cabrerizo, F. J., Chiclana, F., Herrera, F., & Herrera-Viedma, E. (2009). Group decision making with incomplete fuzzy linguistic preference relations. *International Journal of Intelligent Systems*, *24*(2), 201–222. https://doi.org/10.1002/int.20332

Amiri, M., Hashemi-Tabatabaei, M., Ghahremanloo, M., Keshavarz-Ghorabaee, M., Zavadskas, E. K., & Kaklauskas, A. (2021). Evaluating life cycle of buildings using an integrated approach based on quantitative-qualitative and simplified best-worst methods (QQM-SBWM). *Sustainability*, *13*(8), 4487. https://doi.org/10.3390/su13084487

Arora, M., & Kumari, S. (2015). Self-Esteem as determinant of invertors'stock market participation: Mediating role of risk preferences and behavioral biases. *Psychologia*, *58*(3), 115–126. https://doi.org/10.2117/psysoc.2015.115

Atanassov, K. T. (1999). *Intuitionistic fuzzy sets: Theory and applications*. Physica-Verlag. https://doi.org/10.1007/978-3-7908-1870-3

Behret, H. (2014). Group decision making with intuitionistic fuzzy preference relations. *Knowledge-Based Systems*, *70*, 33–43. https://doi.org/10.1016/j.knosys.2014.04.001

Boran, F. E., Genç, S., Kurt, M., & Akay, D. (2009). A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method. *Expert Systems with Applications*, *36*(8), 11363–11368. https://doi.org/10.1016/j.eswa.2009.03.039

Breyfogle III, F. W. (2003). *Implementing Six Sigma: Smarter solutions using statistical methods* (2nd ed.). John Wiley & Sons.

Brix, J., & Lauridsen, O. (2014). Improving learning competencies in the context of radical innovation: A team perspective. *International Journal of Innovation and Learning*, *16*(4), 367–383. https://doi.org/10.1504/IJIL.2014.065544

Brue, G., & Formisano, R. A. (2002). *Six Sigma for managers*. McGraw-Hill.

Brunoe, T. D., Andersen, A. L., Sorensen, D. G., Nielsen, K., & Bejlegaard, M. (2020). Integrated product-process modelling for platform-based co-development. *International Journal of Production Research*, *58*(20), 6185–6201. https://doi.org/10.1080/00207543.2019.1671628

Büyüközkan, G., Göçer, F., & Feyzioglu, O. (2018). Cloud computing technology selection based on interval-valued intuitionistic fuzzy MCDM methods. *Soft Computing*, *22*(15), 5091–5114. https://doi.org/10.1007/s00500-018-3317-4

Cabrerizo, F. J., Alonso, S., & Herrera-Viedma, E. (2009). A consensus model for group decision making problems with unbalanced fuzzy linguistic information. *International Journal of Information Technology & Decision Making*, *8*(01), 109–131. https://doi.org/10.1142/S0219622009003296

Chaira, T. (2011). A novel intuitionistic fuzzy C means clustering algorithm and its application to medical images. *Applied Soft Computing*, *11*(2), 1711–1717. https://doi.org/10.1016/j.asoc.2010.05.005

Chen, Y., Wang, Y., Nevo, S., Benitez-Amado, J., & Kou, G. (2015). IT capabilities and product innovation performance: The roles of corporate entrepreneurship and competitive intensity. *Information & Management*, *52*(6), 643–657. https://doi.org/10.1016/j.im.2015.05.003

Chien-Chang, C. (2010). An integrated quantitative and qualitative FMCDM model for location choices. *Soft Computing*, *14*(7), 757–771. https://doi.org/10.1007/s00500-009-0463-8

Chugani, N., Kumar, V., Garza-Reyes, J. A., Rocha-Lona, L., & Upadhyay, A. (2017). Investigating the green impact of Lean, Six Sigma and Lean Six Sigma: A systematic literature review. *International Journal of Lean Six Sigma*, *8*(1), 7–32. https://doi.org/10.1108/IJLSS-11-2015-0043

Cid-López, A., Hornos, M. J., Carrasco, R. A., & Herrera-Viedma, E. (2015). A hybrid model for decision-making in the Information and Communications Technology sector. *Technological and Economy Development of Economy*, *21*(5), 731–748. https://doi.org/10.3846/20294913.2015.1056281

Cid-López, A., Hornos, M. J., Carrasco, R. A., & Herrera-Viedma, E. (2016). Applying a linguistic multi-criteria decision-making model to the analysis of ICT suppliers' offers. *Expert Systems with Applications*, *57*, 127–138. https://doi.org/10.1016/j.eswa.2016.03.025

Cid-López, A., Hornos, M. J., Carrasco, R. A., & Herrera-Viedma, E. (2018). Prioritization of the launch of ICT products and services through linguistic multi-criteria decision-making. *Technological and Economic Development of Economy*, *24*(3), 1231–1257. https://doi.org/10.3846/tede.2018.1423

Cobo, M. J., López-Herrera, A. G., Herrera-Viedma, E., & Herrera, F. (2012). SciMAT: A new science mapping analysis software tool. *Journal of the American Society for Information Science and Technology*, *63*(8), 1609–1630. https://doi.org/10.1002/asi.22688

Corbett, L. M. (2011). Lean Six Sigma: The contribution to business excellence. *International Journal of Lean Six Sigma*, *2*(2), 118–131. https://doi.org/10.1108/20401461111135019

Cudney, E. A., Venuthurumilli, S. S. J., Materla, T., & Antony, J. (2020). Systematic review of Lean and Six Sigma approaches in higher education. *Total Quality Management & Business Excellence*, *31*(3-4), 231–244. https://doi.org/10.1080/14783363.2017.1422977

Das, P. (2005). Reduction in delay in procurement of materials using Six Sigma philosophy. *Total Quality Management & Business Excellence*, *16*(5), 645–656. https://doi.org/10.1080/14783360500077583

Das, S., Kar, S., & Pal, T. (2017). Robust decision making using intuitionistic fuzzy numbers. *Granular Computing*, *2*(1), 41–54. https://doi.org/10.1007/s41066-016-0024-3

Du, G., Zhang, Y., Liu, X., Jiao, R. J., Xia, Y., & Li, Y. (2019). A review of leader-follower joint optimization problems and mathematical models for product design and development. *The International Journal of Advanced Manufacturing Technology*, *103*(9), 3405–3424. https://doi.org/10.1007/s00170-019-03612-6

Fadly, H. N., & Mohd, Y. S. (2013). Critical success factors of Lean Six Sigma for the Malaysian automotive industry. *International Journal of Lean Six Sigma*, *4*(1), 60–82. https://doi.org/10.1108/20401461311310526

Furterer, S. L. (2016). *Lean Six Sigma in service: Applications and case studies*. CRC Press. https://doi.org/10.1201/9781420079104

Garg, H. (2017). Distance and similarity measures for intuitionistic multiplicative preference relation and its applications. *International Journal for Uncertainty Quantification*, *7*(2), 117–133. https://doi.org/10.1615/Int.J.UncertaintyQuantification.2017018981

George, M. L., Maxey, J., Rowlands, D. T., & Upton, M. (2004). *The Lean Six Sigma Pocket Toolbook: A quick reference guide to nearly 100 tools for improving quality and speed*. McGraw Hill Professional.

Goldstein, M. (2001). Six Sigma program success factors. *Six Sigma Forum Magazine*, *1*, 36–45.

Gündogdu, F. K., Duleba, S., Moslem, S., & Aydın, S. (2021). Evaluating public transport service quality using picture fuzzy analytic hierarchy process and linear assignment model. *Applied Soft Computing*, *100*, 106920. https://doi.org/10.1016/j.asoc.2020.106920

Haber, N., Fargnoli, M., & Sakao, T. (2020). Integrating QFD for product-service systems with the Kano model and fuzzy AHP. *Total Quality Management & Business Excellence*, *31*(9–10), 929–954. https://doi.org/10.1080/14783363.2018.1470897

Huang, Y. Q. (2017). *LDA-based personalized recommendation for Airbnb* [Master's Thesis]. Information Management, Kaohsiung, Taiwan.

Jobber, D., & Ellis-Chadwick, F. (2012). *Principles and practice of marketing*. McGraw-Hill Higher Education.

Kaplan, R. S., & Norton, D. P. (2001). *The strategy-focused organization: How balanced scorecard companies thrive in the new business environment*. Harvard Business Press.

Keshavarz-Ghorabaee, M. (2021). Assessment of distribution center locations using a multi-expert subjective–objective decision-making approach. *Scientific Reports*, *11*, 19461. https://doi.org/10.1038/s41598-021-98698-y

Keshavarz-Ghorabaee, M., Amiri, M., Zavadskas, E. K., Turskis, Z., & Antucheviciene, J. (2018). Simultaneous evaluation of criteria and alternatives (SECA) for multi-criteria decision-making. *Informatica*, *29*(2), 265–280. https://doi.org/10.15388/Informatica.2018.167

Keshavarz-Ghorabaee, M., Amiri, M., Zavadskas, E. K., Turskis, Z., & Antucheviciene, J. (2021). Determination of objective weights using a new method based on the removal effects of criteria (MEREC). *Symmetry*, *13*(4), 525. https://doi.org/10.3390/sym13040525

Kohli, A. K. (2017). Market orientation in a digital world. *Global Business Review*, *18*(3_suppl), S203–S205. https://doi.org/10.1177/0972150917700769

Koskela-Huotari, K., Patrício, L., Zhang, J., Karpen, I. O., Sangiorgi, D., Anderson, L., & Bogicevic, V. (2021). Service system transformation through service design: Linking analytical dimensions and service design approaches. *Journal of Business Research*, *136*, 343–355. https://doi.org/10.1016/j.jbusres.2021.07.034

Laureani, A., & Antony, J. (2018). Leadership – a critical success factor for the effective implementation of Lean Six Sigma. *Total Quality Management and Business Excellence*, *29*(5–6), 502–523. https://doi.org/10.1080/14783363.2016.1211480

Lima, M. B., & Kubota, F. I. (2022). A modular product design framework for the home appliance industry. *The International Journal of Advanced Manufacturing Technology*, *120*(3), 2311–2330. https://doi.org/10.1007/s00170-022-08896-9

Li, X., Su, J., Zhang, Z., & Bai, R. (2021). Product innovation concept generation based on deep learning and Kansei engineering. *Journal of Engineering Design*, *32*(10), 559–589. https://doi.org/10.1080/09544828.2021.1928023

Liu, Y., Bi, J.-W., & Fan, Z.-P. (2017). Ranking products through online reviews: A method based on sentiment analysis technique and intuitionistic fuzzy set theory. *Information Fusion*, *36*, 149–161. https://doi.org/10.1016/j.inffus.2016.11.012

López-Guerrero, A., Hernández-Gómez, J. A., Velázquez-Victorica, K. I., & Olivares-Fong, L. D. C. (2019). Six Sigma as a competitive strategy: Main applications, implementation areas and critical success factors (CSF). *DYNA*, *86*(209), 160–169. https://doi.org/10.15446/dyna.v86n209.76994

Lu, K., Liao, H., & Zavadskas, E. K. (2021). An overview of fuzzy techniques in supply chain management: Bibliometrics, methodologies, applications and future directions. *Technological and Economic Development of Economy*, *27*(2), 402–458. https://doi.org/10.3846/tede.2021.14433

Marasini, D., Quatto, P., & Ripamonti, E. (2016). Intuitionistic fuzzy sets in questionnaire analysis. *Quality* & *Quantity*, *50*(2), 767–790. https://doi.org/10.1007/s11135-015-0175-3

Mardani, A., Jusoh, A., & Zavadskas, E. K. (2015). Fuzzy multiple criteria decision-making techniques and applications – Two decades review from 1994 to 2014. *Expert Systems with Applications*, *42*(8), 4126–4148. https://doi.org/10.1016/j.eswa.2015.01.003

Mishra, A. R., Singh, R. K., & Motwani, D. (2019). Multi-criteria assessment of cellular mobile telephone service providers using intuitionistic fuzzy WASPAS method with similarity measures. *Granular Computing*, *4*(3), 511–529. https://doi.org/10.1007/s41066-018-0114-5

Mishra, A. R., Singh, R. K., & Motwani, D. (2020). Intuitionistic fuzzy divergence measure-based ELECTRE method for performance of cellular mobile telephone service providers. *Neural Computing and Applications*, *32*(8), 3901–3921. https://doi.org/10.1007/s00521-018-3716-6

Mondal, K., & Pramanik, S. (2015). Intuitionistic fuzzy similarity measure based on tangent function and its application to multi-attribute decision making. *Global Journal of Advanced Research*, *2*(2), 464–471.

Morozan, C., & Ciacu, N. (2012). Aspects of online and mobile marketing. *Economy Transdisciplinarity Cognition*, *15*(2), 191–199.

Muthukumaran, G., Venkatachalapathy, V. S. K., & Pajaniradja, K. (2017). Some study on need for L6σ in small scale industries. *Global Journal of Finance and Management*, *9*(1), 15–22.

Nayagam, V. L. G., Muralikrishnan, S., & Sivaraman, G. (2011). Multi-criteria decision-making method based on interval-valued intuitionistic fuzzy sets. *Expert Systems with Applications*, *38*(3), 1464–1467. https://doi.org/10.1016/j.eswa.2010.07.055

Ntepe, G., Bozdag, E., & Koc, T. (2013). The selection of technology forecasting method using a multi-criteria interval-valued intuitionistic fuzzy group decision making approach. *Computers & Industrial Engineering*, *65*(2), 277–285. https://doi.org/10.1016/j.cie.2013.03.002

Ohta, R., Salomon, V. A. P., & Silva, M. B. (2020). Classical, fuzzy, hesitant fuzzy and intuitionistic fuzzy analytic hierarchy processes applied to industrial maintenance management. *Journal of Intelligent and Fuzzy Systems*, *38*(1), 601–608. https://doi.org/10.3233/JIFS-179433

Önüt, S., Kara, S. S., & Isik, E. (2009). Long term supplier selection using a combined fuzzy MCDM approach: A case study for a telecommunication company. *Expert Systems with Applications*, *36*(2), 3887–3895. https://doi.org/10.1016/j.eswa.2008.02.045

Patil, S. K., & Kant, R. (2014). Predicting the success of knowledge management adoption in supply chain using fuzzy DEMATEL and FMCDM approach. *International Journal of Business Performance and Supply Chain Modelling*, *6*(1), 75–93. https://doi.org/10.1504/IJBPSCM.2014.058894

Pei, Z., & Zheng, L. (2012). A novel approach to multi-attribute decision making based on intuitionistic fuzzy sets. *Expert Systems with Applications*, *39*(3), 2560–2566. https://doi.org/10.1016/j.eswa.2011.08.108

Pepper, M. P. J., & Spedding, T. A. (2010). The evolution of Lean Six Sigma. *International Journal of Quality & Reliability Management*, *27*(2), 138–155. https://doi.org/10.1108/02656711011014276

Pereira, M. T., Bento, M. I., Ferreira, L. P., Sá, J. C., Silva, F. J. G., & Baptista, A. (2019). Using Six Sigma to analyse Customer Satisfaction at the product design and development stage. *Procedia Manufacturing*, *38*, 1608–1614. https://doi.org/10.1016/j.promfg.2020.01.124

Pérez, I. J., Cabrerizo, F. J., & Herrera-Viedma, E. (2010). A mobile decision support system for dynamic group decision-making problems. *IEEE Transactions on Systems*, *Man and Cybernetics*, *Part A: Systems and Humans*, *40*(6), 1244–1256. https://doi.org/10.1109/TSMCA.2010.2046732

Pérez, I. J., Cabrerizo, F. J., & Herrera-Viedma, E. (2011). Group decision making problems in a linguistic and dynamic context. *Expert Systems with Applications*, *38*(3), 1675–1688. https://doi.org/10.1016/j.eswa.2010.07.092

Prajogo, D. I. (2016). The strategic fit between innovation strategies and business environment in delivering business performance. *International Journal of Production Economics*, *171*, 241–249. https://doi.org/10.1016/j.ijpe.2015.07.037

Psychogios, A. G., Atanasovski, J., & Tsironis, L. K. (2012). Lean Six Sigma in a service context: A multi-factor application approach in the telecommunications industry. *International Journal of Quality & Reliability Management*, *29*(1), 122–139. https://doi.org/10.1108/02656711211190909

Rani, D., & Garg, H. (2017). Distance measures between the complex intuitionistic fuzzy sets and their applications to the decision-making process. *International Journal for Uncertainty Quantification*, *7*(5), 423–439. https://doi.org/10.1615/Int.J.UncertaintyQuantification.2017020356

Reim, W., Parida, V., & Örtqvist, D. (2015). Product–Service Systems (PSS) business models and tactics – a systematic literature review. *Journal of Cleaner Production*, *97*, 61–75. https://doi.org/10.1016/j.jclepro.2014.07.003

Renaud, J., Fournier, F., Thiébault, J., Lanouette, R., Zaras, K., & Fonteix, C. (2003). Decision-making by rough sets applied to chemical and biochemical multicriteria process optimisation. *IFAC Proceedings Volumes*, *36*(22), 215–220. https://doi.org/10.1016/S1474-6670(17)37720-0

Rodgers, B., Antony, J., Edgeman, R., & Cudney, E. A. (2021). Lean Six Sigma in the public sector: Yesterday, today and tomorrow. *Total Quality Management and Business Excellence*, 32(5–6), 528–540. https://doi.org/10.1080/14783363.2019.1599714

Roy, R., Goatman, M., & Khangura, K. (2009). User-centric design and Kansei Engineering. *CIRP Journal of Manufacturing Science and Technology*, *1*(3), 172–178. https://doi.org/10.1016/j.cirpj.2008.10.007

Sadiq, R., & Tesfamariam, S. (2009). Environmental decision-making under uncertainty using intuitionistic fuzzy analytic hierarchy process (IF-AHP). *Stochastic Environmental Research and Risk Assessment*, *23*(1), 75–91. https://doi.org/10.1007/s00477-007-0197-z

Saghaei, A., & Didehkhani, H. (2011). Developing an integrated model for the evaluation and selection of Six Sigma projects based on ANFIS and fuzzy goal programming. *Expert Systems with Applications*, *38*(1), 721–728. https://doi.org/10.1016/j.eswa.2010.07.024

Salah, S., Rahim, A., & Carretero, J. A. (2010). The integration of Six Sigma and lean management. *International Journal of Lean Six Sigma*, *1*(3), 249–274. https://doi.org/10.1108/20401461011075035

Shamsuzzaman, M., Alzeraif, M., Alsyouf, I., & Khoo, M. B. C. (2018). Using Lean Six Sigma to improve mobile order fulfilment process in a telecom service sector. *Production Planning & Control*, *29*(4), 301–314. https://doi.org/10.1080/09537287.2018.1426132

Singh, S., & Garg, H. (2017). Distance measures between type-2 intuitionistic fuzzy sets and their application to multicriteria decision-making process. *Applied Intelligence*, *46*(4), 788–799. https://doi.org/10.1007/s10489-016-0869-9

Snee, R. D., & Rodenbaugh Jr, W. F. (2002). The project selection process. *Quality Progress*, *35*(9), 78–80.

Son, J., & Kim, S. B. (2017). Content-based filtering for recommendation systems using multiattribute networks. *Expert Systems with Applications*, *89*, 404–412. https://doi.org/10.1016/j.eswa.2017.08.008

Su, C.-T., Chiang, T.-L., & Chiao, K. (2005). Optimizing the IC delamination quality via six-sigma approach. *IEEE Transactions on Electronics Packaging Manufacturing*, *28*(3), 241–248. https://doi.org/10.1109/TEPM.2005.852233

Sunder, M., Ganesh, L. S., & Marathe, R. (2018). A morphological analysis of research literature on Lean Six Sigma for services. *International Journal of Operations & Production Management*, *38*(1), 149–182. https://doi.org/10.1108/IJOPM-05-2016-0273

Szmidt, E. (2014). *Distances and similarities in intuitionistic fuzzy sets*. Springer. https://doi.org/10.1007/978-3-319-01640-5

Tjahjono, B., Ball, P., Vitanov, V. I., Scorzafave, C., Nogueira, J., Calleja, J., Minguet, M., Narasimha, L., Rivas, A., Srivastava, A., Srivastava, S., & Yadav, A. (2010). Six Sigma: A literature review. *International Journal of Lean Six Sigma*, *1*(3), 216–233. https://doi.org/10.1108/20401461011075017

Uluskan, M. (2019). Analysis of Lean Six Sigma tools from a multidimensional perspective. *Total Quality Management & Business Excellence*, *30*(9–10), 1167–1188. https://doi.org/10.1080/14783363.2017.1360134

Vijayan, S. C., Shalij, P. R., & Biju, P. L. (2021, March). Sustainable product development using balanced scorecard perspectives. *IOP Conference Series: Materials Science and Engineering*, *1114*(1), 012060. https://doi.org/10.1088/1757-899X/1114/1/012060

Vink, J., Koskela-Huotari, K., Tronvoll, B., Edvardsson, B., & Wetter-Edman, K. (2021). Service ecosystem design: Propositions, process model, and future research agenda. *Journal of Service Research*, *24*(2), 168–186. https://doi.org/10.1177/1094670520952537

Vinodh, S., & Swarnakar, V. (2015). Lean Six Sigma project selection using hybrid approach based on fuzzy DEMATEL–ANP–TOPSIS. *International Journal of Lean Six Sigma*, *6*(4), 313–338. https://doi.org/10.1108/IJLSS-12-2014-0041

Vukasovi, D., Gligovi, D., Terzi, S., Stevi, Ž., & Macura, P. (2021). A novel fuzzy MCDM model for inventory management in order to increase business efficiency. *Technological and Economic Development of Economy*, *27*(2), 386–401. https://doi.org/10.3846/tede.2021.14427

Wan, S., Xu, G., & Dong, J. (2020). An Atanassov intuitionistic fuzzy programming method for group decision making with interval-valued Atanassov intuitionistic fuzzy preference relations. *Applied Soft Computing*, *95*, 106556. https://doi.org/10.1016/j.asoc.2020.106556

Wang, C.-N., Hsueh, M.-H., & Lin, D.-F. (2019). Hydrogen power plant site selection under fuzzy multicriteria decision-making (FMCDM) environment conditions. *Symmetry*, *11*(4), 596. https://doi.org/10.3390/sym11040596

Wang, W., Yang, B., Zhao, W., & Xie, J. (2019). A deep matrix factorization method with missing not at random data for social recommendation. In T. Gedeon, K. Wong, & M. Lee (Eds,), *Lecture notes in computer science: Vol. 11954. International Conference on Neural Information Processing* (pp. 682–694). Springer, Cham. https://doi.org/10.1007/978-3-030-36711-4_57

Williams, A. L., Mellat-Parast, M., & Adams, S. G. (2012). Employee's perception of the effect of six sigma projects on customer satisfaction. *International Journal of Advanced Operations Management*, *4*(3), 177–194. https://doi.org/10.1504/IJAOM.2012.047635

Xu, Z. (2007a). Intuitionistic fuzzy aggregation operators. *IEEE Transactions on Fuzzy Systems*, *15*(6), 1179–1187. https://doi.org/10.1109/TFUZZ.2006.890678

Xu, Z. (2007b). Methods for aggregating interval-valued intuitionistic fuzzy information and their application to decision making. *Control and Decision*, *2*, 1–19.

Xu, Z. (2011a). Approaches to multiple attribute group decision making based on intuitionistic fuzzy power aggregation operators. *Knowledge-Based Systems*, *24*(6), 749–760. https://doi.org/10.1016/j.knosys.2011.01.011

Xu, Z. (2011b). Intuitionistic fuzzy multiattribute decision making: An interactive method. *IEEE Transactions on Fuzzy Systems*, *20*(3), 514–525. https://doi.org/10.1109/TFUZZ.2011.2177466

Xu, Z., & Yager, R. R. (2008). Dynamic intuitionistic fuzzy multi-attribute decision making. *International Journal of Approximate Reasoning*, *48*(1), 246–262. https://doi.org/10.1016/j.ijar.2007.08.008

Xu, Z., & Zhang, S. (2019). An overview on the applications of the hesitant fuzzy sets in group decision-making: Theory, support and methods. *Frontiers of Engineering Management*, *6*(2), 163–182. https://doi.org/10.1007/s42524-019-0017-4

Xu, Z., & Zhao, N. (2016). Information fusion for intuitionistic fuzzy decision making: An overview. *Information Fusion*, *28*, 10–23. https://doi.org/10.1016/j.inffus.2015.07.001

Zhang, C., Liao, H., Luo, L., & Xu, Z. (2020). Distance-based consensus reaching process for group decision making with intuitionistic multiplicative preference relations. *Applied Soft Computing*, *88*, 106045. https://doi.org/10.1016/j.asoc.2019.106045

Zhang, H., Zhou, R., Wang, J., & Chen, X. (2016). An FMCDM approach to purchasing decision-making based on cloud model and prospect theory in e-commerce. *International Journal of Computational Intelligence Systems*, *9*(4), 676–688. https://doi.org/10.1080/18756891.2016.1204116

Zhang, Q., Irfan, M., Khattak, M. A. O., Zhu, X., & Hassan, M. (2012a). Lean Six Sigma: A literature review. *Interdisciplinary Journal of Contemporary Research in Business*, *3*(10), 599–605.

Zhang, Q., Jiang, L., & Huang, Y. (2012b). An interval intuitionistic fuzzy decision approach for supplier selection in information technology service outsourcing. *Journal of Information and Computational Science*, *9*(15), 4329–4336.

Zhang, W., Du, J., & Tian, X. (2018). Finding a promising venture capital project with TODIM under probabilistic hesitant fuzzy circumstance. *Technological and Economic Development of Economy*, *24*(5), 2026–2044. https://doi.org/10.3846/tede.2018.5494

Zhao, H., Xu, Z., Ni, M., & Liu, S. (2010). Generalized aggregation operators for intuitionistic fuzzy sets. *International Journal of Intelligent Systems*, *25*(1), 1–30. https://doi.org/10.1002/int.20386

Zhao, M., Wei, G., Chen, X., & Wei, Y. (2021). Intuitionistic fuzzy MABAC method based on cumulative prospect theory for multiple attribute group decision making. *International Journal of Intelligent Systems*, *36*(11), 6337–6359. https://doi.org/10.1002/int.22552

Zindani, D., Maity, S. R., & Bhowmik, S. (2019). Fuzzy-EDAS (Evaluation based on Distance from Average Solution) for material selection problems. In R. Narayanan, S. Joshi, & U. Dixit (Eds.), *Advances in computational methods in manufacturing* (pp. 755–771). Springer. https://doi.org/10.1007/978-981-32-9072-3_63

APPENDIX

Details on the most relevant themes of the strategic diagram on P/S design

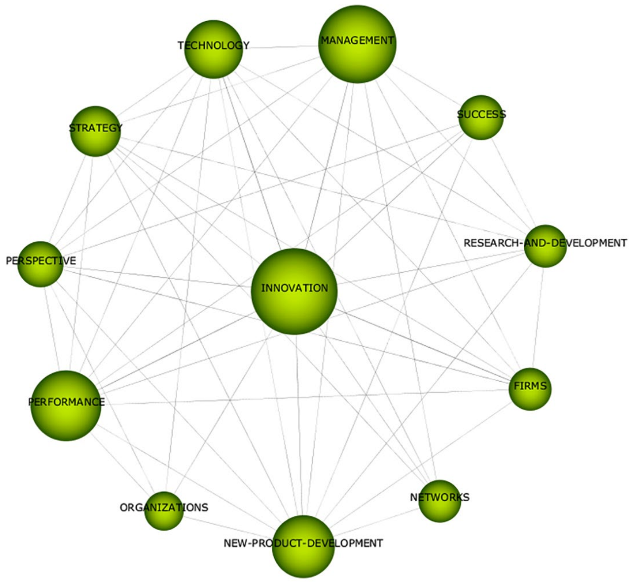

Figure A1. Diagram showing details on the theme INNOVATION

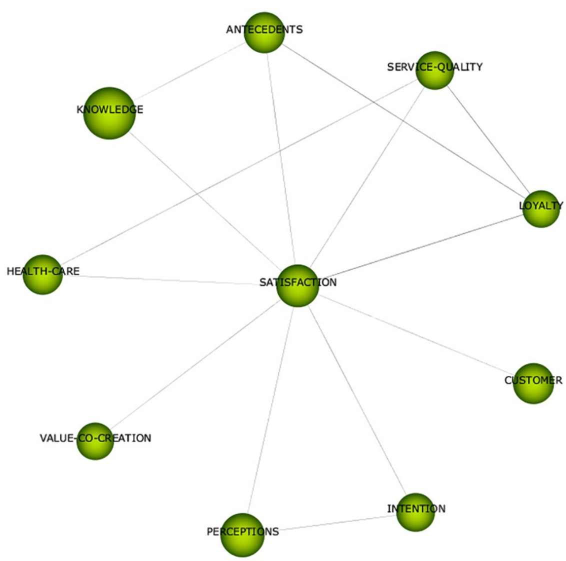

Figure A2. Diagram showing details on the theme SATISFACTION

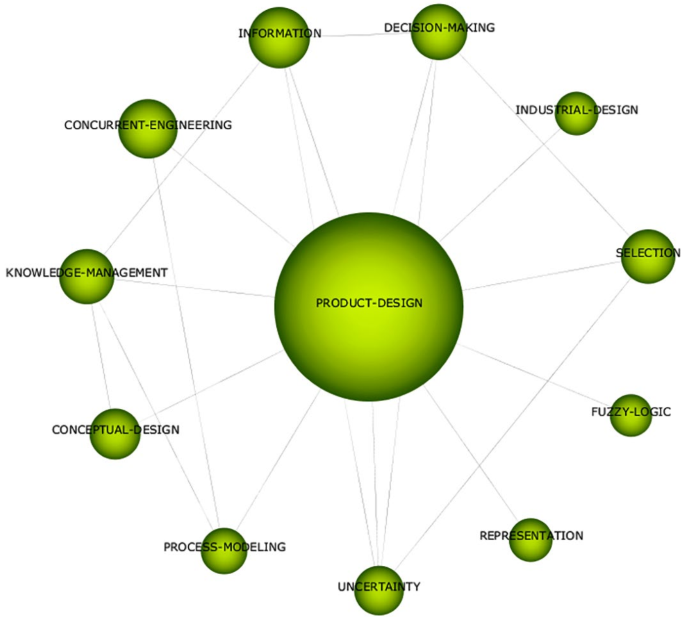

Figure A3. Diagram showing details on the theme PRODUCT-DESIGN

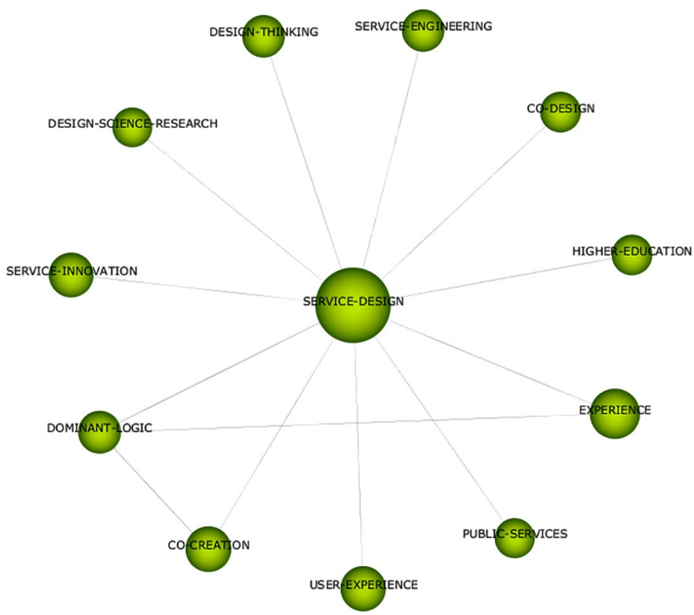

Figure A4. Diagram showing details on the theme SERVICE-DESIGN

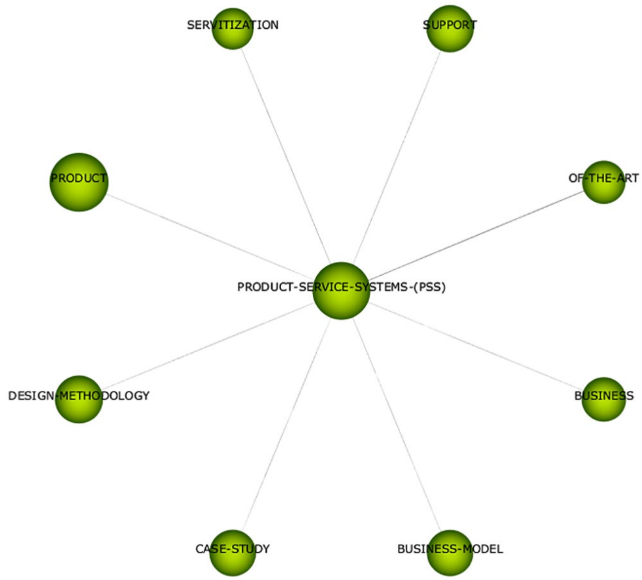

Figure A5. Diagram showing details on the theme PRODUCT-SERVICE-SYSTEMS

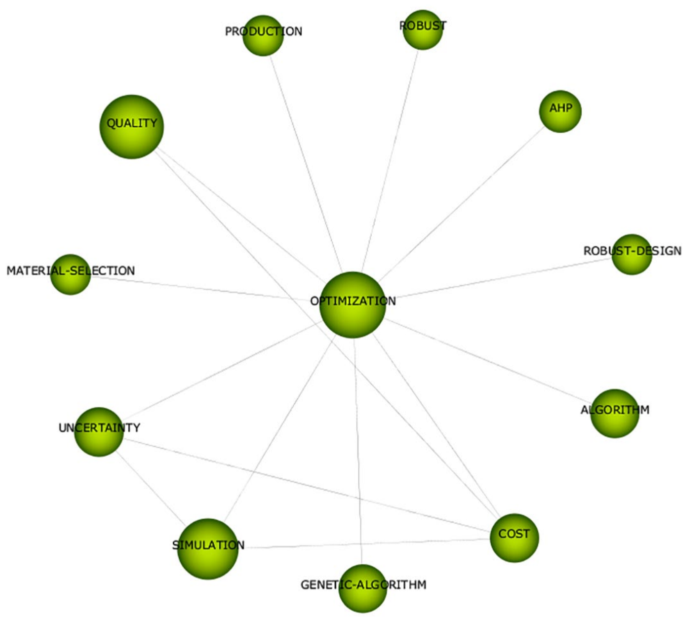

Figure A6. Diagram showing details on the theme OPTIMIZATION

Figure A7. Diagram showing details on the theme QUALITY-FUNCTION-DEPLOYMENT

Figure A8. Diagram showing details on the theme MODULARITY

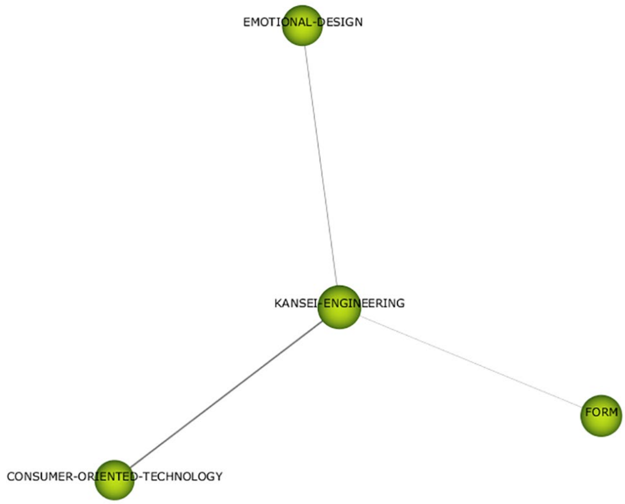

Figure A9. Diagram showing details on the theme KANSEI-ENGINEERING