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A multi-stakeholder system-based methodology to evaluate the needs of innovation ecosystems

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Abstract:

The current nature of innovation projects, which integrate a growing number of stakeholders, is increasing the complexity and scope of the product development process. The understanding of the complex and synergistic dynamics between the entire set of stakeholders requires well-adapted approaches to deal with this complexity since the early stages of a project. The present paper proposes a new methodology, based on the Kano model and needs trade-off methodology for a multi-stakeholders ecosystem during early design stages, enabling to identify and anticipate the needs of an ecosystem of stakeholders. The resulting aggregated Kano matrix enables a holistic vision of the aggregated stakeholders' needs, and then identify emerging needs of the entire ecosystem. The proposed methodology is illustrated through a case study concerning an innovative project of self-directed learning tool apps for smartphones.

Keywords: Innovation; Need analysis; Kano model; Negotiation mechanism; Multi-stakeholder systems.

1. Introduction

The emergence of a new product/process or a new technology causes changes at the technical, economic, regulatory or social level of the company but also on its environment. These impacts could include the company's skills to support customer service (e.g. computers), the flow and channel of information (e.g. internet sales), the manufacturing technologies (i.e. impact of electronics on mechanical systems in the automotive industry). These changes are critical for the success of future products and services; consequently, anticipating these impacts represents a key factor. Indeed, designing a new product or service requires considering the needs of potential customers, but also these of the concerned stakeholders within the innovation ecosystem. It should be noted that in this research, a need is considered a necessity, a lack of tacit or implicit dissatisfaction experienced by a user, whereas a requirement is a statement that reflects a need (Badreau and Boulanger, 2014). The requirement is then, a formalized need.

There is a consensus regarding the relevance of the tasks in the upstream phases of a project (Börjesson et al., 2006; Cooper et al., 2002). The upstream phases are also commonly known as "Front-End" activities (FE) or Front End of Innovation (FEI). Current methodologies seeking to evaluate the potential success of a new product and its subsequent impacts are devoted to identifying and classifying the needs of customers. Some of these approaches are based on the Kano model; they allow the project manager to identify which customer requirements of a particular product or service might bring more proportional satisfaction to them. The set of studies of (Ben Rejeb et al., 2008; Kano et al., 1984; Li et al., 2009; Tontini, 2003; Xu et al., 2009; Wang and Hsueh, 2013; Wang, 2013) lead to the identification, classification, and prioritization of the set of customer needs in a structured and quantitative manner.

However, several studies have shown that final customers' preferences are not the only determinant for innovation success, but also those of the set of stakeholders in the innovation environment, so their specific needs must also be formalized and evaluated. Hence, impacts on stakeholders such as prescribers, intermediaries, control institutions or suppliers, among others, have to be studied. Indeed, the studies of (Jiao and Zhang, 2005; Xu et al., 2009), argue that companies should not rely solely on customers to develop innovations, since customers are not often experts and are not always well informed. Moreover, the current nature of products and services causes the new project development process (NPDP) to rise in complexity and scope, increasing the number of stakeholders involved in it. As stated by (Wood et al., 2012), if these relations are ignored or not understood, the project may enter into an "uncharted stakeholder minefield." Thus, the concept of innovation ecosystems of stakeholders is increasingly accepted to explain these complex and synergistic dynamics between stakeholders in an innovation process.

Research of (Ben Rejeb et al., 2008; Witell et al., 2011) proposed a methodology that considers simultaneously the needs of several stakeholders, which is a fundamental aspect during the management of a new product development process. The authors highlight several concepts to identify stakeholders' needs. Firstly, needs are characteristics of an individual or a group of stakeholders and are elements that affect the global activity of the user and are linked to the notion of dependence (between customer performance and the product used). A given individual or group is more or less able to describe precisely the elements affecting its process and behavior, which may create differences between demands and needs. Secondly, from a systemic point of view, needs are input features, representing elements that must be at the stakeholders' disposal. As a result, needs analysis may be considered a resource's issue for accomplishing customer activities (Morel and Boly, 2006).

Many stakeholders are usually involved in the product life cycle, which means that a major concern for designers is taking into consideration the different needs related to this multi-stakeholder environment. Moreover, complementary and opposite needs emerge while defining and identifying all stakeholders' requirements. Hence, designers and project managers must make decisions related to prioritizing needs during the front-end phases of the innovation process. The proposed method is based on a mapping of needs, which is an early step for defining priorities in terms of the needs that the new product must fulfill. This mapping also determines the needs classification according to the theory of attractive quality.

However, within the already mentioned need analysis methodologies, the evaluation of the stakeholders' needs is carried out individually without considering interactions and trade-offs among them. As a consequence, new approaches are required in order to identify the aggregated needs of the entire ecosystem of stakeholders, which are not necessarily the sum of the individual needs. This is an important point, when working with participatory approaches such as living lab methodologies, where stakeholders with different preferences interact to co-create new products or services (Pallot et al., 2010). Starting from a description of individual needs, the research objective is to elaborate and test a methodology that assists designers when defining priorities within the set of targeted needs to be satisfied by the new product (or technology). In addition, the methodology is inspired by the work of Kano, with a few differences. Indeed, the traditional Kano focuses essentially on the user, whereas the one proposed in this article is a multi-stakeholder Kano model. To reach this model, the present paper proposes a new methodology based on multi-criteria analysis, enabling representation of the needs of a set of stakeholders in an innovation ecosystem. The relevance of the proposed methodology to represent and formalize the network of stakeholders and its dynamics (dependency and interaction) is evaluated. Then, a new impact assessment methodology based on multi-criteria analysis is proposed and illustrated through a project dealing with smartphone application development under a living lab approach.

2. Overview of Kano Model and Multi-criteria approaches

2.1 Fuzzy-Front-End Needs Assessment: from Kano Model to Quantitative Approaches

Innovative companies' attention is directed towards customers and general needs description within the early stages of projects. In addition to traditional methods for identifying needs, such as interviews, "voice of the customer" tools and focus groups, some companies use the model proposed by Kano in the theory of attractive quality (Kano et al., 1984). Kano argued that there are four types of customer needs (see Figure 1):

- One-dimensional (O): The more efficient the product is, the more the customer is satisfied.
- Attractive (A): If the product is not performing, the customer does not realize the problem. But if the product is better than others on the market, it becomes differentiation and the customer is more satisfied.
- Must-be (M): The customer requires a minimum performance, below which it is not satisfied; but if there is an improvement, the customer's satisfaction does not increase.
- Indifferent (I): The performance has no interference in customer satisfaction

These customer needs can be classified through a customer questionnaire, in which half of each pair of questions focuses on how the customer would feel if a product being developed included a particular capability; these are referred to as the "functional questions." The other half of each pair considers how the customer would feel if the capability is not provided; these are the "dysfunctional questions" (Berger et al., 1993). The requirement classification is obtained by combining the two answers to the functional and dysfunctional answers of each respondent. Then, according to the frequency of answers, the dominant customer view determines the needs classification (Berger et al., 1993).

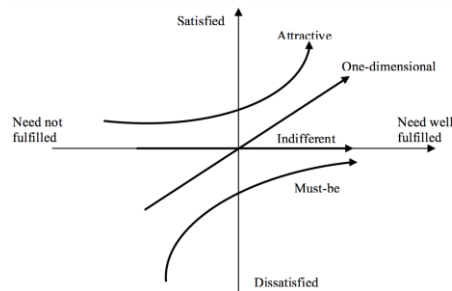


Figure 1 Kano model (Kano et al., 1984)

Furthermore, other researches introduced improvements with the calculation of Kano indices that are quantitative measurements of customer satisfaction (Haber et al., 2020; He et al., 2017; Witell et al., 2011). Tontini adds an index measuring the “reverse degree” of the requirement, and consequently the robustness of each need formulation. Secondly, instead of using the frequency of answers given by the Kano evaluation table, Tontini proposed transforming each possible answer to the questionnaire into a score ranging from -2 to +2; these ratings are then used to calculate new indicators. This method uses the respondents’ answers directly, preserving the voice of the customer more effectively than simply scoring the answers as attractive, one-dimensional, must-be, indifferent, and so on individually for each respondent (Tontini, 2003). This modification makes it possible to use the Kano model as a quantitative measure of the customer’s level of satisfaction.

More recent studies have validated the relevance of these quantitative approaches. (Li et al., 2009; Rashid et al., 2011; Sharif Ullah and Tamaki, 2011; Gupta et al., 2018). These authors try to reduce the uncertainties and improve the robustness of the Kano model application. In particular, regarding the research of Sharif Ullah and Tamaki (2011), their approach seeks to validate the relevance (type of need) of design features for an already existent product or prototype. Moreover, they still focused on set of customers (even if there are different types of them). So, there is still a lack of methodologies proposing a more holistic point of view. That is, considering the whole ecosystem of stakeholders around the potential innovation and how it could change their needs.

2.2 Multi-Stakeholders needs analysis trade-off

Hence, within a complex system, the behavior of the whole system could not be only explained by the characteristics of its individual components, but also by their interactions. In the same way, in the innovation process the needs of the whole system could not be defined exclusively through those of the consumers. As needs are numerous, sometimes opposite and often contradictory, designers have to synthesize need analysis outcomes to elaborate the specification of the future product. A set of priorities are required to engage the technical design of the product and the elaboration of the business plan. In other words, a product development process involves a phase where a trade-off of stakeholders’ needs should be “negotiated” to produce a conclusive list of needs.

From the point of view of an innovation project, dealing with stakeholders’ needs could lead to conflicts that affect the design team performance. As shown in Figure 2, solving these conflicts is an iterative process that allows progressively identify and find compromises that fit as good as possible the sociotechnical system of stakeholders needs through a period of time (Lu and Cai, 2001).

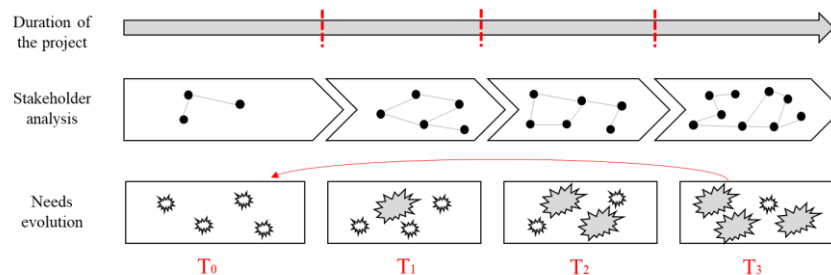


Figure 2. Sociotechnical design process (adapted from [Lu and Cai, 2001])

From our literature review, the already existent needs analysis methodologies seem limited and not sufficiently adapted to integrate since T_0 the dynamic characteristics of the network (Figure 2). This means anticipating the negotiations and compromises that will take place in the downstream phases of the project as early as T_0 . Indeed, the needs analysis methodology is a static, descriptive model that allows to describe the individual needs of the actors without illustrating the possible compromises between the stakeholders. Particularly the computation of an aggregated set of needs, resulting from the dynamic negotiation among actors, should enable to anticipate as soon as possible and have a better comprehension of the interaction among stakeholders and then open the possibility to draw scenarios as a consequence of perturbation on the system resulting from the new product introduction.

The current development of the multicriteria decision analysis (MCDA) field enables to support this needs aggregation process. Indeed, among a number of MCDA techniques, the AHP (Analytical Hierarchical Process) has been selected (Saaty, 2008) to illustrate the proposed approach. This technique has been selected because its pairwise comparison approach which allows decision makers to determine in an easy and transparent manner the importance degree (weights) between the set of concerned criteria. Moreover, it proposes the evaluation of consistency of decisions and has been used by the design community for a trade-off between design features during the product design process (Jiao et al., 2007; Li et al., 2009).

Moreover, the goals and needs of each stakeholder within the innovation system will be represented by an ecosystem of stakeholders. Its capabilities of negotiation, cooperation and competition among actors (Lesser, 1999) will be applied in order to aggregate and prioritize the needs of the set of stakeholders involved in a particular innovative supply chain. In this research, a methodology proposed for the negotiation aspect and applies it to stakeholders, not agents. For this reason and to avoid confusion, the term Multi-Stakeholder System (MSS) will be used in this article. The next section will describe the defined methodology and negotiation mechanisms to aggregate the set of needs.

3. Proposal of a Network Needs' Aggregation Methodology

The main goal of the proposed aggregated needs analysis is to identify a concern matrix of needs, named M_0 , this matrix including the set of needs of the stakeholders' network. These needs resulting from internal negotiation among the stakeholders, and categorized and prioritized as being 1) *Attractive* (A), 2) *One-dimensional* (O), 3) *Must-be* (M), and 4) *Indifferent* (I), as defined by the Kano model. Considering the Front-End phases as a temporal framework for the requirement analysis, the following overview of the methodology can be proposed (see Figure).

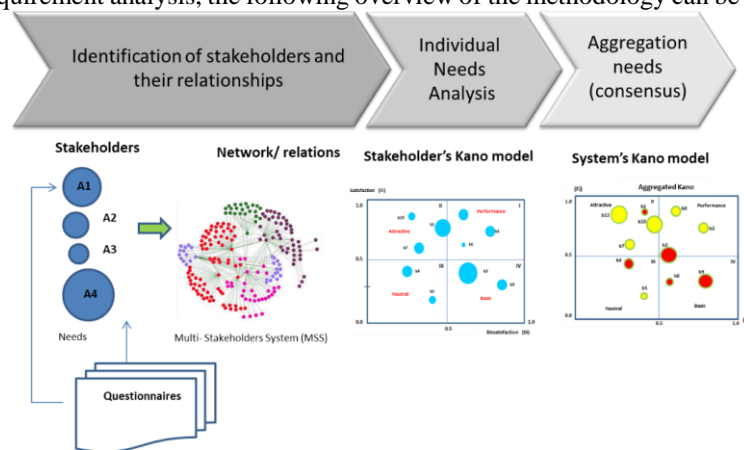


Figure 3 An overview of the methodology for needs identification and assessment.

The proposed methodology to consolidate individual needs has two preparatory phases that enable the representation of the network of innovation stakeholders as an MSS, then to generate the negotiations between the different stakeholders in a third step. Each step will be explained and developed in the following sections, considering the scheme of Figure, which summarizes more precisely the different stages of the proposed methodology.

Different approaches were pursued in order to test the proposed methodology. In line with constructivist principles, the methodology is considered validated as long as the designers who are to take further management

decisions use its outcomes, and team members agree to give the necessary information to complete the grids. The main criteria are then the pertinence of the methodology within the company's decision process and the acceptability for people involved in the new product development process. One case study will be presented in conjunction with the proposed methodology. It concerns the evaluation at the Fuzzy Front End stage of the feasibility of self-directed learning through smartphone applications; more details about the subsequent stages of this project can be found in (Camargo et al., 2012) and then, are out of the scope of the present paper. The choice of this case study can be justified in several ways: (i) it is an important innovation project because it is based on the concept of self-learning a language (a concept that was not yet very widespread in the field of smartphone applications by the time the experimentation was done), (ii) it is positioned in the final stages of the upstream phase of innovation and (iii) it includes a different set of stakeholders (learners, developers, suppliers or instructors, among others) for whom it is difficult to identify and prioritize the needs that will determine further development. Within the present study, an experimental survey was carried out to determine the aggregated needs of the individuals and structures involved in the project.

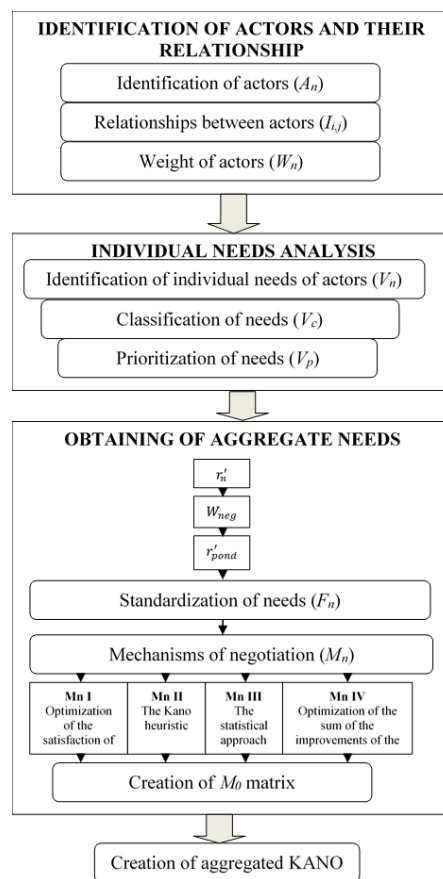


Figure 4 Detailed aggregated KANO methodology

3.1. The identification of stakeholders and their relationship

In most of the projects, the new product development team could provide a context description and the identification of a set of stakeholders denoted as $A = \{A_1, \dots, A_n\}$, where n is the number of stakeholders and a set of weights representing the degree of importance of each stakeholder, denoted as $W = \{W_1, \dots, W_n\}$. Then, the ordered pair, $(A_i, W_i), \forall i \in \{1, \dots, n\}$, represents the i -th stakeholder and its corresponding weight. Moreover, the relationship between two unique stakeholders A_i and $A_j, \forall i \in \{1, \dots, n\}, \forall j \in \{1, \dots, n\} - \{i\}$, denoted as I_{ij} , takes a value from the set $\{0,1\}$. As such, $I_{ij} = 0$ means, there is no relation between A_i and A_j , whereas $I_{ij} = 1$ means there is a relation between A_i and A_j .

Each stakeholder's weight could be the result of the company's marketing analysis, but it could also be systematically deduced from a value analysis. However, some methodologies of stakeholder analysis, e.g.

MACTOR (Godet, 1991) or Design Structure Matrix (Eppinger and Browning, 2012) which are based on matrix analysis, could help to validate and refine this choice, obtaining the interrelationship between the stakeholder i and stakeholder j ($I_{i,j}$). The principle of Design Structure Matrix consists of analyzing the dependencies among the constituent elements of products, process and organization (Eppinger and Browning, 2012) in order to visualize its internal couplings (Bonjour, 2008). The principle of MACTOR consists of establishing a correlation matrix between individuals; the presence of a relation between two stakeholders is modeled with 1, or 0 in case of absence of the interrelation, as above explained. When summing the lines and rows of the matrix, it is possible to calculate the number of relations of a stakeholder within his environment and then calculate his importance, or weight on the network. The MACTOR method seems better suited to our study because it makes it possible to determine the weight of the actors within the network, which is not negligible in a negotiation process. The goal is to obtain a network representation of the stakeholders as shown in Figure 5:

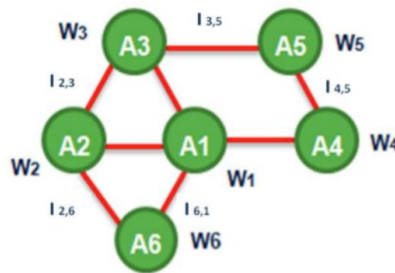


Figure 5: Representation of a stakeholders' network.

In this representation a network is shaped by 6 stakeholders $A = \{A_1, \dots, A_6\}$ each one being characterized by his weight W_n and relationship ($I_{i,j}$ With i and $j \in n$).

For particular case study, thirteen main stakeholders were identified (Table 1). For each type, an importance a weight was computed by using a pairwise comparison between stakeholders of the network following the method of the MACTOR symmetric matrix as proposed by (Godet, 1991). Identifying relationships between different innovation stakeholders according to their dependence on the product is crucial. The table below allows us to analyze the existence of a relationship between stakeholders ($I_{i,j}=1$ "relationship" or $I_{i,j}=0$ "no relationship"). The column N represents the total number of relationships between stakeholders.

Code	Name of the stakeholder	W_n	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	N
A1	Users	11.0%	-	1	1	0	0	0	1	1	1	1	1	0	1	8
A2	Creative team	8.3%	1	-	1	0	1	1	1	0	1	1	1	1	1	10
A3	Management team	8.3%	1	1	-	1	0	1	1	0	1	0	0	0	1	7
A4	Advertising	7.1%	0	0	1	-	0	0	0	1	1	1	0	1	0	5
A5	Support and Funding	6.0%	0	1	0	0	-	1	0	0	0	0	1	1	1	5
A6	Programmers	8.4%	0	1	1	0	1	-	1	0	1	1	0	0	0	6
A7	Suppliers	6.9%	1	1	1	0	0	1	-	1	1	0	0	1	0	7
A8	Telephone companies	6.5%	1	0	0	1	0	0	1	-	1	0	0	0	0	4
A9	Indirect competitors	8.0%	1	1	1	1	0	1	1	1	-	1	0	0	1	9
A10	Substitution competitors	8.0%	1	1	0	1	0	1	0	0	1	-	1	0	1	7
A11	Educational establishments	7.2%	1	1	0	0	1	0	0	0	0	1	-	1	1	6
A12	Ministry and institutions	6.3%	0	1	0	1	1	0	1	0	0	0	1	-	1	6
A13	Professor of English	8.0%	1	1	1	0	1	0	0	0	1	1	1	1	-	8
		100%														88

Table 1 The stakeholders, their weights and the relationship between stakeholders

3.2 Individual needs analysis

3.2.1 Identification of needs of stakeholders (V_n)

The method proposed to identify the stakeholders' needs, called RARe, is described in detail in (Morel and Boly, 2006). Firstly, needs are characteristics of an individual or a group. They constitute elements that affect the global activity of the user and are linked to the notion of dependence (between customer performance and the product used). Hence, the first step to understanding needs consists of describing the functioning modes of a stakeholder. A systemic model is used to indicate the outcomes, the activities and inputs of an individual. Figure gives the case of the model of a student in the educational sector.

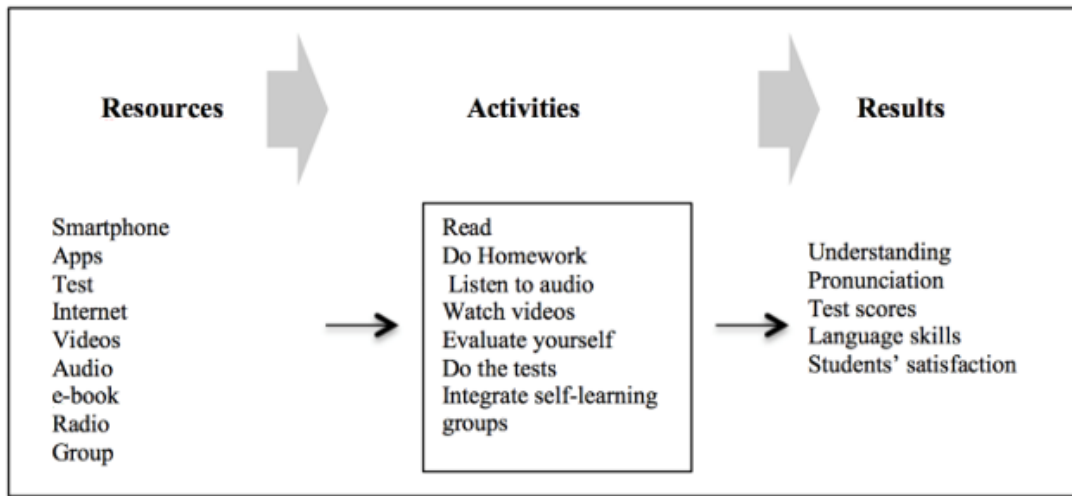


Figure 6: Model of the functioning mode of a student with the proposed approach

In a second step, (Morel and Boly, 2006) suggest studying the problem of resources that the considered individual faces to improve his personal outcomes in terms of quantity or quality. Each resource problem is then assimilated to a need and a list of needs is established. An in-depth understanding of the context during the first step makes it easier to formulate needs, particularly implicit ones.

Then, as explained in section 2, the Kano model of customer satisfaction defines the relationship between product attributes and customer satisfaction and provides four types of needs (T): (*A*), (*O*), (*M*) and (*I*). The combination of *functional* and *dysfunctional* answers is then used to identify the status of the attribute in terms of the needs of each stakeholder that is represented by the vector (Vc_{An}). This vector represents the ordered list of needs related to each class:

$$(1)Vc_{An} = \{n_{iA}, \dots, n_{iO}, \dots, n_{iM}, \dots, n_{iI}\}$$

With: $A, O, M, I \in T$ with $W_A > W_O > W_M > W_I$

n_{iM} , need identified by the stakeholder A_n and positioned in its category T (*A*, *O*, *M* or *I*)
 i , the total of identified needs for the stakeholder (A_n).

By using the RARe model (Boly et al., 2000) a set of needs has been identified. For example, for our case study, stakeholder A_1 has twenty potential needs, as well as stakeholder A_2 who is seventeen (See Table 2). Also, it could be further observed that some common needs could appear for several stakeholders of the innovation network, whereas there are others which are specific to a stakeholder.

Code	Description of the need	Actor A ₁	Actor A ₂
N1	Simple and easy to use tool	X	X
N2	Availability of a place to leave suggestions and comments for the webmaster	X	
N3	Lean interface to give answers to requests	X	
N4	Right price	X	
N5	Innovative method of self-learning offered by the application	X	X
N6	An application to learn anywhere, anytime	X	
N7	Exercises and activities adapted to the user's level of learning	X	X
N8	Reliability given by the user profile that assesses the activity or submitted content (expert or learner)	X	X
N9	Tracking graphics and charts of the user's progress	X	X
N10	A simple filing system so that the user can submit new content in the application	X	X
N11	A system that can receive and give tips and advice for solving exercises	X	X
N12	The ability to access a community of learners (to have contact with other learners, share, evaluate others' exercises)	X	X
N13	Tool with playful fun (games, colors ...)	X	X
N14	Data privacy and profile	X	
N15	Not too heavy application	X	X
N16	Tool regularly updated	X	
N17	Offline use option of the application	X	
N18	Technological revolution (new support or versions)	X	X
N19	Simultaneous evaluation of the written and listening level of the learner	X	X
N20	Compatibility of versions	X	
N21	Recognition of innovation, social image provided by the application		X
N22	An easy name to remember		X
N23	Creation of complementary products		X
N24	One evolutionary programming language to another (which can easily be integrated into technologies and other media)		X
N25	The same application to other fields of knowledge		X
N26	Data access and user profiles		
N27	Product popularity		
N28	An application that allows the actor to showcase himself, his institution, his job ...		
N29	Association of the name of the actor with the product (recognition and disclosure of the actor)		
N30	Programming product controlled by the programmer		
N31	Demand for more expensive packages, with internet		
N32	An additional product substitution competitor		
N33	An additional resource for teaching		
N34	A tool that facilitates learning		
N35	Providing new options for technological support		
N36	Influencing product through newly launched trends (technology, ecology, legal ...)		
N37	Student-teacher relationship that endures		
N38	Product known by a small number of people		
N39	Application functioning only with internet connection		

Table 2: Example of needs of the stakeholder A₁ and stakeholder A₂

3.2.2 Needs classification and prioritization.

The method used is inspired by those proposed by (Tontini, 2003). Each customer need is defined by a ratio depending on functional to dysfunctional answers.

To better classify the needs in each category, (Berger et al., 1993) proposed the Customer Satisfaction Coefficient (CSC). CSC calculates the percentage of customers that become satisfied (F_i) with the positive question and the percentage that become dissatisfied with the negative question (D_i). These two values are plotted in a scatter diagram divided into four quadrants. The quadrants classify the needs as $T = \{A, O, M, I\}$. To do this, the relation index (r_i) is used. The r_i represents (Figure 7) the absolute distance between each customer need $n_i = (D_i, F_i)$ and the origin point of each quadrant $PC_i = (PC_{iX}, PC_{iY})$.

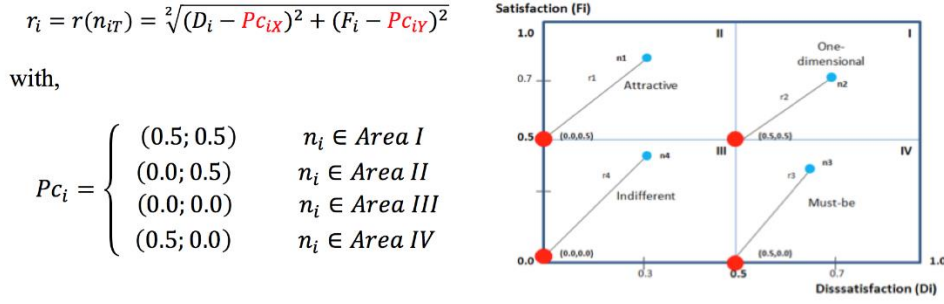


Figure 7: The indicator (r_i) of relation of satisfaction.

The value of r_i leads to ranking the needs belonging to the type of need. Then, for each stakeholder A_n , a vector Vp_{An} , of categorized and prioritized needs will be obtained.

$$(2) Vp_{An} = \{n_{iT.1}, \dots, n_{iT.k}, \dots, n_{iT.h}, \dots, n_{iT.j}\}$$

With $n_i \in V_c$ with $i =$ total number of needs for the stakeholder (A_n),
T: type of needs $T = \{A, O, M, I\}$
 j, h, k : rank of each need within its type of need, regarding (r_i), with $j > h > k > 1$.

For each stakeholder a specific vector is obtained in which each requirement figures and is classified in order of importance: first, the attractive needs classified by r , then the neutral needs. Each type of stakeholder has his own (Tontini, 2003)'s diagram, and each stakeholder has a vector with a classification of its own.

Once the set of needs V_c is described, the Tontini indices (D_i, F_i) and the relation index (r_i), enabling us to prioritize each need, are calculated. Table 3 shows the prioritized set of needs for stakeholder A_I of our case study.

Needs	Fi	Di	Type of needs	r_i
1	0.920	0.326	A	0.5320
2	0.601	0.362	A	0.3763
3	0.790	0.696	O	0.3497
4	0.893	0.804	O	0.4965
5	0.623	0.312	A	0.3351
6	0.841	0.406	A	0.5298
7	0.768	0.464	A	0.5357
8	0.341	0.022	I	0.3413
9	0.804	0.181	A	0.3542
11	0.623	0.471	A	0.4869
12	0.428	0.101	I	0.4394
13	0.717	0.326	A	0.3919
14	0.717	0.710	O	0.3024
15	0.507	0.551	O	0.0512
16	0.580	0.196	A	0.2113
17	0.688	0.449	A	0.4872
18	0.554	0.089	A	0.1041
19	0.857	0.304	A	0.4687
20	0.750	0.839	O	0.4214

Table 3: Computation of the relation index (r_i) for A_I

Figure 8 shows the sorting of the stakeholders' needs represented graphically as well as their categorization as Attractive, One-directional, Must-be and Indifferent $T = \{A, O, M, I\}$. In this case, of the 20 needs identified for the stakeholder A_I , 12 were classed as attractive (A), 5 as one-dimensional (O), and 3 as Must-be (M) needs respectively.

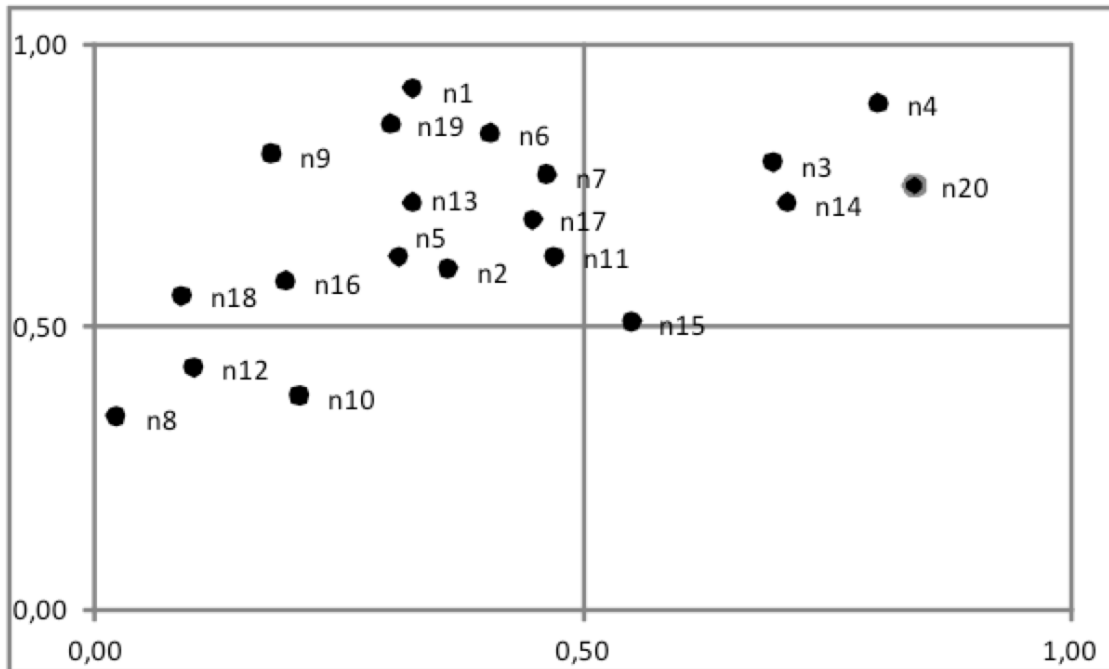


Figure 8: The graph of needs of the stakeholder A_1 : Abscise is D_i and F_i the ordinate

Thanks to the arrangement by type of need given by the index r_i , every need has been assigned a weight to establish a ranking within the categories. The vector (Vp_{An}) is obtained for A_1 (Table 4), to be able to compare the needs with other stakeholders.

Type of need	A	A	A	A	A	A	A	A	A	A	A	A	O	O	O	O	O	I	I	I
V_p	7	1	6	17	11	19	13	2	9	5	16	18	4	20	3	14	15	12	10	8
r_i	0.536	0.532	0.530	0.487	0.487	0.469	0.392	0.376	0.354	0.335	0.211	0.104	0.496	0.421	0.350	0.302	0.051	0.439	0.431	0.341

Table 4: The vector of prioritized needs (Vp_{An}) , for A_1

3.3 Obtaining aggregate needs

In a Multi-Stakeholders System, a negotiation mechanism is a key form of interaction enabling stakeholders to deal with conflicts and reach a going consensus. It is a process in which disputing stakeholders decide how to divide the gains from cooperation. This decision-making depends on factors such as the number of negotiators, the number of issues to be negotiated, the type of issues (i.e., divisible or indivisible), and the stakeholders' utility functions (Kraus, 2001).

Within the context of the present research, two stakeholders A_1 and A_2 could have different types of conflicts to deal with:

- They could have a completely or partially different set of needs, where $Vp_{A1} \neq Vp_{A2}$.
- They could have the same needs, with Vp_{A1} and Vp_{A2} having the same set of elements in the same categories of need, but a different order of priorities (ranking of the needs).

In both cases, the aggregation process must establish a new vector of needs for the network's set of stakeholders.

After identifying and prioritizing the individual needs of each stakeholder, their weight and their relationships, aggregate needs are obtained, representing all the stakeholders of innovation. Aggregate needs of the system are obtained on the basis of three steps. As shown in Figure 9, determining the stakeholders (A_n), their weight (W_n), their relationships ($I_{i,j}$) and their needs (V_p) provides the aggregated needs of the system through three stages of MSS: normalization with the negotiation factor (F_n), negotiation with the negotiation mechanism (M_n) and aggregation with the matrix of negotiations (M_0).

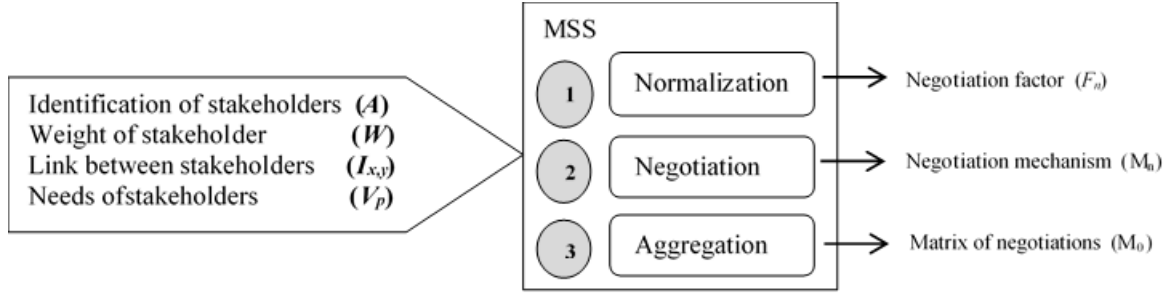


Figure 9: Research of a needs consensus

The first step normalizes needs to be comparable to initiate negotiations between agents, according to the mechanisms of negotiation. Thereafter, aggregation of the needs is carried out based on the matrix of negotiations called M_0 . The negotiation factor (F_n) is computed in order to normalize the vectors and translate the effect of each stakeholder's importance (W_n) into his needs.

3.3.1 Standardization of needs (F_n)

The mechanism of negotiation is represented by a set of matrix equations, including the self-defined importance of each stakeholder W_n and also its vector of individual needs Vp_{An} . As the number of needs for each stakeholder could be different, a negotiation factor (F_n) is defined, in order to normalize the different Vp_{An} vectors. It is computed as a function of:

- the number of needs,
- the type of these needs $T = \{A, O, M, I\}$,
- the relative importance of the stakeholder (W_n)
- its relation of satisfaction index r_i .

The negotiation factor F_n is obtained as follows:

- a. Considering the sum of r_i , as a net satisfaction of a stakeholder ($\sum r_i$) it must be ensured that his/her weight is a good representation of his/her relative importance W_n as a function of the number of needs concerning this stakeholder. In terms of a negotiation between two stakeholders A_1 and A_2 , the values of r_i must be normalized and weighted by the sum of the net satisfaction of both stakeholders ($A_1 \wedge A_2 \in A_n$) because it is difficult to ensure that the net satisfaction of a stakeholder will be greater than that of another stakeholder. This means that:

Given, W_1, Vp_{A1} with $n_i \in A_1 \wedge W_2, Vp_{A2}$ with $n_j \in A_2$ and; $W_1 < W_2$

Where $i > j \wedge \sum_1^i r_i < \sum_1^j r_j$, the normalized values of r'_i and r'_j are defined as:

$$(3) \quad r'_i = \frac{r_i}{(\sum_1^i r_i + \sum_1^j r_j)} \times 100 \quad \text{and} \quad r'_j = \frac{r_j}{(\sum_1^i r_i + \sum_1^j r_j)} \times 100$$

The normalized values of r'_i and r'_j are obtained by dividing each r_i by the total sum of r_i of the two stakeholders involved in the negotiation.

- b. Considering the fact that the weight of the stakeholders W_n must be a function of the network of stakeholders, there is a relative weight of each negotiation W_{neg} . This weight of negotiation represents the importance of the stakeholder according to who has negotiated with him; it is defined as:

$$(4) \quad W_{neg1} = \frac{W_1}{W_1 + W_2} \quad \text{and} \quad W_{neg2} = \frac{W_2}{W_1 + W_2}$$

- c. So, values of r'_i could be weighted considering the relative importance of each stakeholder generating standardized and weighted $r'_{i\text{weight}}$ based on the stakeholders' weight of negotiation W_{neg} as:

$$(5) r'_{i\text{weight}} = r'_i \times W_{neg1} \quad \text{and} \quad r'_{j\text{weight}} = r'_j \times W_{neg2}$$

Giving the next dependency relationship:

$$(6) \frac{\sum_1^i r'_{i\text{weight}}}{\sum_1^i r'_i} = W_{neg1} \quad \text{and} \quad \frac{\sum_1^j r'_{j\text{weight}}}{\sum_1^j r'_j} = W_{neg2}$$

In this way, the standardization of values r_i can be placed on the number of needs of each vector Vp_{An} , depending on the weight of the stakeholder, on a common scale.

- d. The negotiation factor F_n could then be obtained as the product of the need weight (W_T); and the relation index normalized and weighted ($r'_{i\text{weight}}$). This factor makes it possible to start the negotiation mechanisms among stakeholders:

$$(7) F_{ni} = r'_{i\text{weight}} \times W_T$$

In this way, a direct relationship could be established between the stakeholders' weights and their negotiation factor (F_n):

$$\text{If: } (8) W_i < W_j \in W_n \Leftrightarrow \sum_1^i F_{ni} < \sum_1^j F_{nj}$$

Where the negotiation factor (F_n) is associated with each need n_i belonging to the vector (Vp_{An}), to assign the relative importance of each stakeholder to his needs.

Regarding the present case study, the negotiation factor is computed as follows: to determine the importance of the needs (W_T) of the stakeholders, a multi-criteria analysis technique AHP—Analytical Hierarchical Process (Saaty, 2008) was used, finding in this case: the attractive needs are preferred to the one-dimensional, i.e., $W_A=0.54 > W_O=0.25 > W_M=0.15 > W_I=0.06$.

Table 5 shows, the values of the normalized values r'_i and r'_j and $r'_{i\text{weight}}$ which are necessary to compute F_n , to start the negotiations between two stakeholders (A_1 and A_2).

Stakeholder	$W_I = 11,0\% \quad W_{neg} = 57,0\%$																			
A_1																				
Type of need	A	A	A	A	A	A	A	A	A	A	A	A	O	O	O	O	O	O	O	
V_p	7	1	6	17	11	19	13	2	9	5	16	18	4	20	3	14	15	12	10	8
r_i	0.54	0.53	0.53	0.49	0.49	0.47	0.39	0.38	0.35	0.34	0.21	0.10	0.50	0.42	0.35	0.30	0.05	0.44	0.43	0.34
r_i^p	3.20	3.17	3.16	2.91	2.90	2.80	2.34	2.24	2.11	2.00	1.26	0.62	2.96	2.51	2.09	1.80	0.31	2.62	2.57	2.04
r_{pond}^p	1.822	1.810	1.802	1.657	1.656	1.594	1.333	1.280	1.205	1.140	0.719	0.354	1.689	1.434	1.190	1.029	0.174	1.495	1.468	1.161
F_n	0.984	0.977	0.973	0.895	0.894	0.861	0.720	0.691	0.651	0.615	0.388	0.191	0.422	0.358	0.297	0.257	0.044	0.090	0.088	0.070
Stakeholder	$W_I = 8,3\% \quad W_{neg} = 43,0\%$																			
A_2																				
Type of need	A	A	A	A	A	A	A	A	A	A	A	O	O	O	O	O	O	O	O	O
V_p	5	7	12	19	18	9	15	24	25	8	10	11	13	1	21	22	23	23	4	4
r_i	0.71	0.63	0.63	0.63	0.56	0.45	0.45	0.45	0.35	0.25	0.71	0.53	0.52	0.45	0.45	0.35	0.52	0.50	0.50	0.50
r_i^p	4.22	3.73	3.73	3.73	3.33	2.69	2.69	2.69	2.11	1.49	4.22	3.16	3.07	2.69	2.69	2.11	3.07	2.98	2.98	2.98
r_{pond}^p	1.812	1.602	1.602	1.602	1.433	1.155	1.155	1.155	0.906	0.641	1.812	1.359	1.321	1.155	1.155	0.906	1.321	1.281	1.281	1.281
F_n	0.979	0.865	0.865	0.865	0.774	0.624	0.624	0.624	0.489	0.346	0.453	0.340	0.330	0.289	0.289	0.227	0.079	0.077	0.077	0.077

Table 5: Calculation of negotiation factor, for A_1 and A_2

This method helps to formalize the individual preferences and goals of the stakeholder considered. Moreover, as the number of identified needs for each stakeholder could be different, the average of the obtained F_n does not allow representation of the aggregated needs of the network.

3.3.2 Mechanism of negotiation (Mn)

Once the factor of negotiation is defined, several mechanisms could be proposed and tested. More precisely, we propose four mechanisms of negotiation; these four different mechanisms are achieved to elaborate a collective model of needs. These mechanisms are based on different strategies. The first and second mechanisms state that the stakeholder having the greatest power on the ecosystem will succeed in directing attention to his own need. Even if the negotiation includes a win/win approach, the individual weight of the stakeholder remains a major variable. On the other hand, the third mechanism is more global; complementary to negotiation by pairs, it highlights needs that are more commonly present all over the ecosystem. In a way, it gives more importance to the collective dimension of needs. Finally, the fourth mechanism tries to give opportunities for a dual positive result in the negotiation between two stakeholders. The mechanisms are described below:

- *The optimization of the satisfaction of each pair of stakeholders considered (Mn I):* this mechanism consists of the maximization of the stakeholders' satisfaction as well as the satisfaction of the Kano model priorities of needs. It is an optimization approach where the negotiation factor F_n of a need is maximized between the two vectors of needs when comparing two stakeholders. The negotiation factor F_n integrates then, the importance of each of the two considered stakeholders A and B into the negotiation (W_A and W_B).
- *The Kano heuristic (Mn II):* This mechanism is based on the notion of preference of one stakeholder. Preferences are dependent upon the weight of the considered need P_T , and its category (A, O, M, or I). It means that for each evaluated need the heuristics will prioritize the Kano preferences (A > O > M > I)
- *A statistical approach (Mn III):* the aim is the identification of a need that has a major presence in the set of stakeholders (the statistic mode). The frequency of the attribute of a particular need (its category and negotiation index F_n) within the need set is determined.
- *The optimization of the sum of the improvements of the negotiation factor of the two considered stakeholders (Mn IV):* This mechanism is based on the calculation and the comparison of the improvement of the total satisfaction of the two considered stakeholders. It considers the action of the first choice of the agent, according to the sum total of satisfaction achieved for each of these choices, so as to achieve a balance in the final satisfaction of both stakeholders. The principle is a win/win negotiation.

Each negotiation mechanism allows us to generate a vector v_{Mn} that promotes a stakeholder according to a few parameters. Thanks to these mechanisms, two stakeholders can generate their negotiations on the basis of four options, not to foster a sole stakeholder by using a single negotiation mechanism. The resultant vector is the representation of prioritizing needs according to the chosen mechanism.

For our case study, the multi-criteria simulation was implemented and performed using a Madkit© (platform ("MaDKit," 2002). Table 6 shows the negotiation vector between Stakeholders A_1 and A_2 , resulting from the maximization of satisfaction mechanism (Mn I), explained in 4.2 and highlighting needs having the maximum value of F_n .

Type	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	O	O	A	O	A	O	O	O	O	O	I
Vp	7	5	1	6	17	11	12	19	18	13	2	9	15	24	25	10	4	16	20	8	3	21	14	22	23	
Fn	0.984	0.979	0.977	0.973	0.895	0.894	0.865	0.865	0.774	0.720	0.691	0.651	0.624	0.624	0.489	0.453	0.422	0.388	0.358	0.346	0.297	0.289	0.257	0.227	0.079	

Table 6: Vector of negotiation between A_1 and A_2

Also, this mechanism optimizes the satisfaction of a set of stakeholders, on the basis of the indicator of negotiation (F_n), which considers the importance of each stakeholder, as well as the number of that stakeholder's needs. The Kano representation of the resultant negotiation between A_1 and A_2 is shown in Figure . The black circles represent the set of needs that remain unchanged from the stakeholder A_1 's point of view. The white circles represent the set of negotiated needs (trade-offs between A_1 and A_2). The squares represent the needs added by stakeholder A_2 .

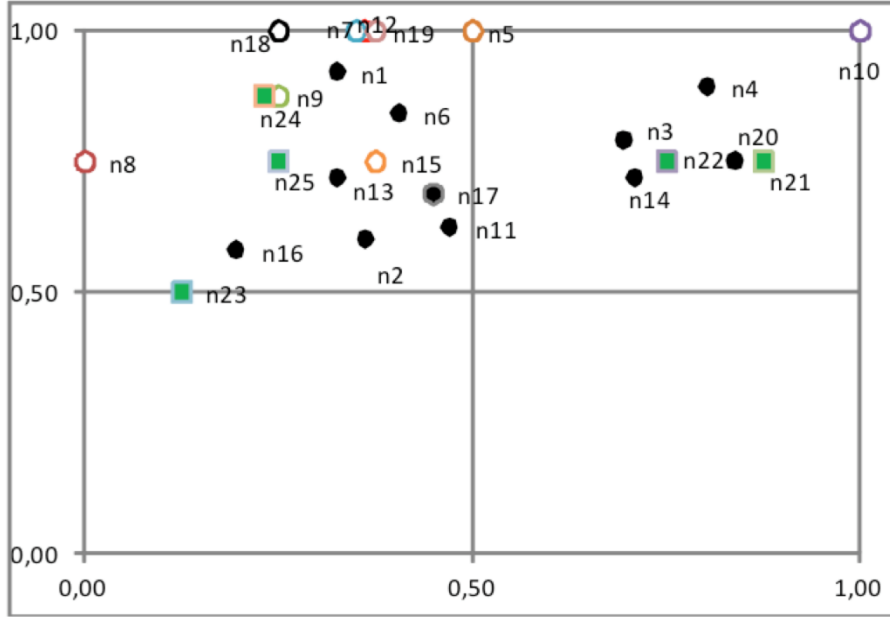


Figure 10: The graph of needs for the negotiation between A_1 and A_2

3.3.3 Creation of M_0 matrix

The previously proposed mechanism applied to the set of stakeholders allows us to create the matrix of negotiation $N_{m \times n}$ where the whole set of vectors resulting from each dual negotiation are arranged according to the relationships among stakeholders. In line with the matrix, each negotiation vector is obtained after a pairwise negotiation. As each stakeholder is confronted with another stakeholder that does not have the same needs, this is not a square matrix.

This matrix is therefore composed by the union of the row matrices:

$$(9) N_{m \times n} = v_{MnI}(A_1 - A_n) \cup v_{MnII}(A_x - A_y) \cup v_{MnIII}(A_x - A_n) \cup v_{MnIV}(A_y - A_n),$$

with $A_x, A_y \in A$.

Given the position of each need within the matrix and its mode, the concern vector (M_0) could be generated:

$$(10) x_{i.m} = \max\{f_j, j \in \{1,2, \dots, k\}\}$$

with $x_{i.m} \in \text{line } m$

Giving a vector VM_0 :

$$(11) VM_0 = \{n(x_{1m}), n(x_{2m}), n(x_{3m}), \dots, n(x_{im+1}), \dots, n(x_{nm})\}$$

This vector is a representation of the best equilibrium among the stakeholder's preferences of the network. The needs were negotiated and ordered considering the importance level of each stakeholder, which enables decision-makers to establish the set of needs best representing the preferences of the stakeholders influenced by a new product.

The methodology proposed above allows innovation project decision-makers to identify the individual needs of each stakeholder influenced by the appearance of the new products and/or services. Based on the four mechanisms of negotiations, a negotiation matrix is generated and makes it possible to reach a consensus among stakeholders, thereby generating the aggregated Kano, which provides a comprehensive view of the needs of global stakeholders.

To sum up the global approach, the proposed methodology starts with a description of the needs of individuals based on resource problems considering their mode of functioning. Then, each need is characterized by different

elements: satisfaction distance in the Kano map r_i , and a negotiation function F_n . Then, to obtain an aggregation reorientation of the needs inside a global stakeholder network, different negotiation approaches are achieved, giving a final vector and classification of all the needs considered.

Finally, regarding our case study, given the weight of the stakeholders, the relations between stakeholders, and the vectors of needs in the right order, negotiations can begin. The set of all negotiations among the stakeholders leads to matrix M_0 of 44 rows and 25 columns. A fragment of the matrix is shown in Figure .

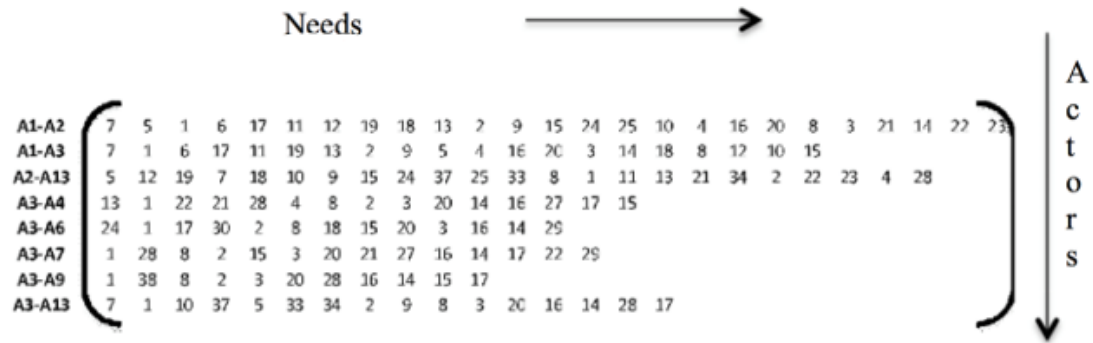


Figure 11: Fragment of the negotiation matrix

Given the concern matrix, the concern vector VM_n indicates the whole set of network needs, from the peer-to-peer negotiations among the whole set of stakeholders, prioritized and sorted according to different types of needs. This vector represents the initial order of importance of needs for the entire network of stakeholders.

Once finished, the set of negotiations enables decision-makers to analyze the differences between the basic data (individual needs) and the aggregation outcomes. Figure 12 shows the aggregated Kano matrix, after the whole set of negotiations have been finished. Some considerations could be made:

- It can be observed that of a total of 39 needs of the 13 stakeholders, their distribution according to the final negotiation is as follows: 23 attractive (A), 8 one-dimensional (O), 7 Indifferent (I) and 0 Must-be (M).
- In the same figure, it can be observed that there are three groups of needs after negotiations. The red circles represent needs that evolved after the negotiation process. The blue circles represent needs that remain unchanged. Finally, the squares represent specific needs belonging to a single stakeholder.
- Moreover, some needs could change for the stakeholder A_I before and after the consideration of the negotiations between the different stakeholders of the network (RAI). More precisely, it can be seen that need number 8 (reliability given by the user profile that assessed the activity) that initially was considered by stakeholder 1 (A_I), as being indifferent, becomes attractive once it is negotiated. Likewise need number 1 (simple and easy to use tools) that is attractive to stakeholder 1 (A_I), after negotiating with the rest of the stakeholders turns out to be one-dimensional.

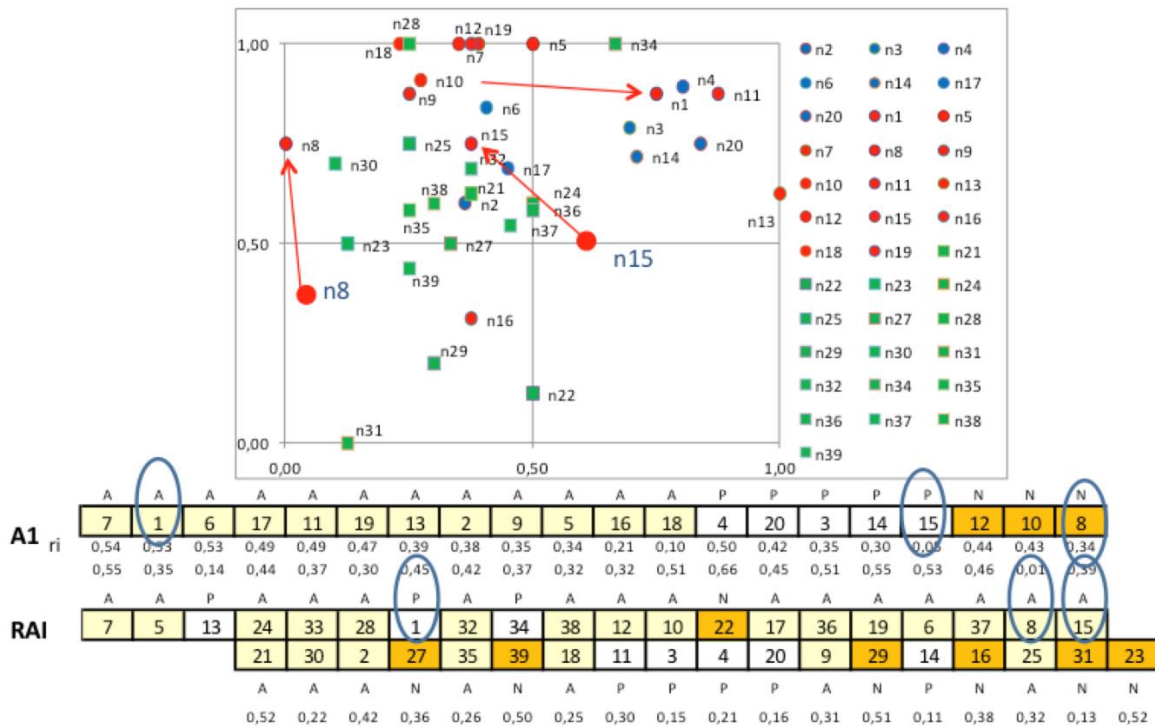


Figure 12: The needs for the whole network and Differences between the graph of needs for stakeholder A1 before and after the negotiations

3.3.4 Discussion of the case study

These results lead us to believe that the proposed method considers more specifically the needs of the users. For the manager of an innovation project, this means a better orientation and targeting of potential project concepts, based on the prioritized needs of the stakeholders, and this from the upstream phases of the project (Fuzzy Front End). More specifically, some situations can be cited in which decision-making can be improved thanks to analysis such as this presented in Figure 12. First, the allocation of development resources towards meeting collective priority needs. Second, the identification and targeting of needs that are not a priority for the customer but which, due to their frequency of appearance, can be decisive for all the set of stakeholders, and therefore determine the success or failure of the new product. To finish, the establishment of “if... then...” type scenarios and the visualization of its impacts in terms of the orientation of the design project and innovation, for example.

As mentioned in section 3, more details about the subsequent stages of this project can be found in (Camargo et al., 2012), which was more focused on the experimental approach to define the set of needs and then out of the scope of the present paper. However, the implementation of the methodology allows to mention that as with any proposed method, the experimentation carried out has shown us the limits and ways to improve our approach. First of all, the application of the method can be expensive and take a considerable amount of time in some cases. For some projects, where time is a limit important this can be a blocking factor for the application of the method. Similarly, the way the questionnaires are set up (functionality/dysfunctionality), and the subjective nature of the answers given, require prior in-depth reflection. Finally, the number and nature of individuals, representing the actors to be surveyed, will define the relevance and the degree of statistical significance of the results obtained.

4. Implications for the New Product Development Decision-Making Process

Whereas the major contribution of this paper will be described as methodological, it also has to be situated in the context of practitioners of an innovation project (Yip et al., 2019). The next point aims to discuss some of these implications:

- The first stage of the method “identification of stakeholders and their relationship” is key when deploying the methodology. As we observed in the case study, the process of building a formalized network of concerned stakeholders allows us to identify stakeholders and relationships that weren’t expected, as designers are focused on user needs at this early stage. This allows the development team to think from the beginning of the project about possible blocking points and enablers and how to deal with them.
- Perhaps the most promising implication of the proposed methodology is the simultaneously holistic and dynamic landscape of the project Multi-Stakeholders—System (MSS)’ needs. This property will allow decision-makers to establish prospective scenarios on the potential *impacts* of a new product on the stakeholders’ network. This notion of *impact of an innovation* needs to be further explored and formalized. As the introduction of an innovation will act as a “disruption/disturbance” on its environment of stakeholders, these disruptions will lead to the emergence of new relations among the stakeholders, apparition/disappearance of some of them, or even preference evolution of one, or more of the stakeholders’ ecosystems.
- The proposed representation based on a Multi-Stakeholders System (MSS) will allow project managers and designers to represent the previously described phenomena and lead to sensitivity analysis—for example, modifying the specific weight of one of the stakeholders or integrating new stakeholders into the system to evaluate the needs’ evolution of the entire system.
- A central result of the proposed model is the matrix of negotiations M_0 that summarizes the aggregated needs of the stakeholder. In order to integrate these capabilities into the multi-criteria-based model, it was necessary to introduce two new concepts; the relation index (r_i) makes it possible to normalize and compare the needs of the different stakeholders, and the negotiation factor (F_n), which introduces into the negotiation matrix the degree of importance of each stakeholder. These concepts could be further discussed and improved.
- As illustrated within the present case study, the dynamic capability of the model of providing need trajectories on the KANO space will allow designers to have a better understanding of the collective needs in order to integrate them when defining product specifications.

Within our methodological approach the selected framework was the KANO model but an adaptation to the VOA approach could be considered as a perspective. Following the design decision repository of the Carnegie Mellon University¹, it states that the VOA is used to “expose how valuable a product is to the user. One can compare how the worth of a new design to an older or more generic design. In addition, amended products could also be analyzed through the VOA in order to get a better understanding of whether the changes made were an improvement or not” (Cagan et al., 2002). However, to the best of our understanding, one difference with need analysis is the fact that for the VAO analysis an already existent product or potential new concept is analyzed to identify how valuable it is for the customer. On the other hand, the Need analysis does not require that a technical solution or well-defined product to be studied yet, as it is centered on identifying potential needs (tacit or explicit) for each stakeholder before any consideration on the product itself. As a consequence, we infer that the Need analysis assessment is most likely for an up-stream phase on the design process.

5. Conclusion

A new methodology to identify the needs of an ecosystem of stakeholders at the Fuzzy Front End of an innovation project was proposed. The aggregated Kano matrix allows decision-makers to have a holistic vision of the aggregated stakeholders’ needs from data gathered to a sample of the identified stakeholders using a Kano questionnaire. Then the individual needs are prioritized and sorted in one of the needs defined by the Kano methodology (A, O, M, I). A discussion of the literature on the complex nature of the innovation ecosystem of stakeholders was made. The proposed methodology based on the Multicriteria Decision theory enables stakeholders to find needs trade-offs. The aggregation process of individual needs results from a negotiation mechanism based on the stakeholder’s relative importance and interactions within his system.

¹ https://wiki.ece.cmu.edu/ddl/index.php/Value_opportunity_analysis

The application of the proposed methodology has enlightened its potential contribution to the prioritization of resource allocation at the Fuzzy Front End of the innovation project, and then improvement of its effectiveness. This poses some implications for a decision-maker, for example:

- Identify differences in individual and collective needs; so forecast the relative impact of some needs to define the product design needs
- Consider positive and negative synergistic effects.
- Follow the trajectory of the needs as negotiations are going forward.

As far as this field of research is at an early stage, there is a set of perspectives and potential improvements that this application has shed light on. First, new negotiation mechanisms could be developed and a benchmarking of mechanisms must contribute to a better understanding of this aggregation phenomenon. Second, a very interesting path to be explored concerns the implications of availability of the (M_0) matrix of concern to anticipate impacts of the introduction of an innovation (new product or service) as a disturbance to the ecosystems of stakeholders.

In this article, we studied the impacts on stakeholders at the Fuzzy Front End of the design process. One of the perspectives now consists of anticipating these impacts on the various stakeholders in order to design as early as possible the structure of the supply chain in the most suitable way. But also consider the methodology in areas such as the design of the service layout, where several stakeholders interact, having different needs or desires.

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