Design for innovation – A methodology to engineer the innovation diffusion into the development process

Marco Cantamessa [a], Francesca Montagna [a], Gaetano Cascini [b,*]

[a] Politecnico di Torino, C.so Duca degli Abruzzi 24, 10129 Torino, Italy
[b] Politecnico di Milano, Via La Masa 1, 20156, Milano, Italy

In its hyper-inflated usage, innovation simply means "something new", and is applied to any technical novelty. In its true meaning, innovating means designing something that will not only work under a technical point of view, but will also make business sense. "Design for Innovation" means considering that design cannot simply focus on a narrow meaning of "product use", because this could severely limit the diffusion of innovative products. The paper proposes an original model for representing what we call "beyond-use situations" and the influences among the actors involved in the innovation diffusion process.

Taking inspiration from social influence network models and from the Multi-issue Actor Strategy Analysis Model (MASAM), the paper presents an operational methodology to assess the influence of different actors on the decision to adopt a new product. In turn, such methodology should support design teams to conceive novel solutions more likely to become factual innovations. The paper also describes a computer-implementable technique, loosely derived from Quality Function Deployment, to practically apply the proposed methodology. An industrial case study from the medical-care sector illustrates its logic and operational steps.

Keywords:
Innovation diffusion
Multi-stakeholder
Multi-issue Actor Strategy Analysis Model
Native needs
Reported needs

1. Introduction

Over the last two decades, product development scholars and practitioners have studied success factors in innovation (see for instance [1–5]), and many of them have embraced the idea that products should be developed with a clear focus on customer needs. A variety of techniques have been proposed for this purpose, ranging from market research techniques aimed at understanding customer needs [6–8], to methods whose objective is their translation into product requirements and specifications [9,10]. In general, these methods share the assumption that customers have a set of more or less tacit needs and that – given a product that adequately fulfills these needs – those customers will decide to purchase the product, thus ensuring product success in the market.

When moving from B2C (Business-to-Consumer) to B2B (Business-to-Business) markets, and/or when dealing with highly innovative products, really this kind of translation becomes more complex. In these cases, products' attractiveness and customer needs are connected to product use, but products must be conceived considering that customers may be embodied by different actors with different roles and expectations, such as buyers, users, and beneficiaries.

In the case of buses for public transport, for instance, the buyer is the purchasing office of a local transport authority, the users are its employees, such as bus drivers and maintenance crews, and the direct beneficiaries are the passengers who buy a ticket and ride the bus. However, there are also external stakeholders, such as citizens being affected by the emissions of the vehicle, or passers-by that may be impacted by the bus – quite literally in fact – in case of an accident. Moreover, many other actors will interact within the diffusion process, such as officials from the City hall, environmental activists, and so on. In the case of medical devices for hospital use, the customer as a buyer is the hospital's purchasing office, the users are the medical staff, the direct beneficiaries are the patients, and outsiders may include patients' relatives or employers. As a final example, when deciding on the equipment to be installed during the renovation of a house, some members of the family will be buyers, users and beneficiaries;

* Corresponding author.
E-mail addresses: marco.cantamessa@polito.it (M. Cantamessa), francesca.montagna@polito.it (F. Montagna), gaetano.cascini@polimi.it (G. Cascini).

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Nomenclature

$pos_{i,j}$	position, direction toward which an actor perceives his or her own goals with respect to the need
$sal_{i,j}$	salience, degree with which the realization of the favorable outcome is relevant to the actor's overall objectives
$imp_{i,j}$	importance attributed by actors to their native needs
$inf_{i',i,j}$	influence that actor i might undergo due to actor i' with respect to issue j
N	number of actors
$a_{ii,j}$	*susceptibility* of actor i to interpersonal influence on the issue j

other members (e.g., young children) will only be beneficiaries, and installers may have a role as users.

Inspiration for this paper has hence come from our direct experience in interacting with product development teams. Multiple times we have heard representatives from the sales functions raise issues such as "what is the value to the user of this function?", "the product is good, but it won't be easy to get the 'sales pitch' through when talking to purchasing managers" or "firms will probably buy it, but they won't get addicted enough to its use to make repeat purchases".

Moreover, often literature tells us that many apparently well-conceived products have failed in the market [7,11,12], and this again suggests that product success probably has to do with a much broader view of "customer needs". At the same time, the way customers are involved in the development process is not a neutral process for companies, and can affect the way firms are perceived in the marketplace, as well as the own customer intentions [13,14].

It is in order to gain this broader view, that authors started thinking about the innovation diffusion process in its entirety as an essential unit of analysis for developing products.

Innovation Management literature has plenty of definitions for innovation. Most of the time, scholars follow the definition of innovation as the "commercial exploitation of an invention" [15]. Nevertheless, if one adopts the definition proposed by the Merriam Webster dictionary, which states that innovation is "*the act or process of introducing* [something] *new*", this definition points to the interesting concept of "innovation as introduction".

This introduction can be in sales channels, in the purchasing process carried out by firms and, of course, in the current use that might make the product not renounceable to a mass of users. A product will be successful only if it successfully makes it through these multiple "introductions", being considered innovation if it eventually results adopted and diffused. Consequently if a product does not diffuse, it cannot be considered an innovation whatever is its novelty and performance, and this implies that when well-conceived products fail in the market, they fail in being innovation; and this happens not necessarily for technological reasons, but because the introduction and the adoption process fail.

Of course, this perspective requires considering innovation diffusion as the complex and multi-stakeholder process that it really is. In fact, a new product will become a successful innovation only when all the actors involved will favorably align their attitude toward its "introduction" in the portion of the process they play a role in, and this implies broadening the meaning that is usually given to the term "customer needs".

It was in order to gain this broader view, that authors started thinking about the innovation diffusion process as an essential unit of analysis for developing products, through the consideration that this requires engineering the product adoption process and analyzing all the "customer needs" that emerge. This implies, going back to the examples above, that in order to design innovative medical devices, designers must take care of the entire adoption process, considering the needs of the medical staff (which is usually considered even now), the needs of the patient and the ones of the purchasing office that expresses the final decision on the adoption for the hospital. Without neglecting that these people live in organizations and therefore influence each other's needs.

Following this line of thought, the research challenge that naturally emerges is to define approaches that might enable firms to systematically conceive and design products, so that "user needs" are considered in this rather broad sense, looking at all the actors involved in the adoption and considering their mutual influences.

This leads obviously to define approaches that foster synergies between marketing and R&D. The need for integrating these two business units is well known in literature [16,17], however none of the current contributions proposes tools that can be practically deployed for supporting the product development process to the extent that is required.

The paper has the research objective of filling this gap by proposing a methodology – loosely derived from Quality Function Deployment (QFD) and suitable to embed in a computer application – for engineering the adoption process within product development, by modeling the customer needs and requirements through a multi-stakeholder perspective. This is the main contribution, which sets this paper apart from previous literature on requirements capture.

This research develops and structures the preliminary empirical findings by Shluzas et al. [18], who presented a case study on identifying and managing value in a multiple-stakeholder envi-ronment and extends, engaging with its multiple-user perspective, other contributions [19] that propose the use of "requirements clusters" in order to manage complex situations. Other authors proposed the use of integrating Value Analysis and QFD [20]. However, their objective was more general and it did not directly address those specific elements of design process that affect the adoption process.

From a methodological point or view, the research approach comprises the mapping of the adoption process and the analysis of all the actors whose needs could affect it. This study should be performed by different cycles of interviews that help to identify the relevant actors, their needs and the importance respectively attributed. Properly carried out interviews allow to extract influences among actors. The formal analysis of these influences implies the definition of the metrics to be used and the definition of the formal procedure for the aggregation of the gathered data; it can be performed by using methods borrowed from sociology, such as Social Network and Actor Network Analysis. The use of such methods in the context of product design and development is not very common, with Wadell and Norell Bergendahl [21] being one notable exception. This singularity defines a further element of originality of this research.

The next session clarifies in further details the objectives of this research and the validation approach followed by the authors.

2. Needs and requirements in product design and development literature

As mentioned in the Introduction, a cornerstone of modern product development is the understanding of customer needs, often termed "the Voice of the Customer" [22], and their translation into product requirements.

"Needs" indeed represent the basic motivation for pushing people to change their situation [23–25], and hence they are at the basis of customer adoption decisions. Belch and Belch [26] even explicitly considered consumer needs as an output of consumers' decision-making problems, as well as the importance of widening the perspective toward the customer behavior, in order to correctly define product requirements, is definitively recognized in market-ing literature [27–30].

Nevertheless, in addition to the marketing literature, many other authors from diverse fields provide evidence that firms should focus on customer and market needs for new product development. In Engineering Design, marketing-oriented issues are considered success factors of product development projects [31–33], and also design approaches inspired by TRIZ, in identifying possible future scenarios for a given product, positioned the product of the anticipatory design tasks with respect to the clusters of consumers they intend to address [34–36].

More recently, the "customer need" concept in Engineering Design has been quickly broadened considering the role of emotions, psychological issues and emotional designs [37,38]. These studies in particular, require a deeper understanding of customers' perception of value, given their "life space", and the cultural and usage context in which they live.

In architecture or industrial design, instead, the problem of framing needs by keeping the social context into account and creating a social design process were largely assimilated. Since Alexander's seminal contributions [39], this literature has been highlighting the need for social acceptance of artifacts, and now this view finds its modern manifestation in the many approaches that advocate "participative design" of solutions to societal problems [40].

Additionally, in industry, topics such as "co-design" or "participatory design" are the evidence of the importance of considering the user/customer's perspective in design.

Therefore, a firm may use the term "need" for analyzing the sheer technical functionality of a product, or may widen its view and address cultural, psychological and emotional aspects as well. The most disruptive innovations are in fact the ones that blend a novel technical solution to a need that is deeply and widely felt by customers, but was previously unaddressed because the technology was not available, because industry did not consider it, and because customers were not even aware of it.

Contrasted to needs, requirements can be defined as "structured and formalized information about a product" which "consists of a metric and a value" (e.g., [10]). Information captured from the customer's context therefore must be converted into information that is usable by technical personnel for designing and developing the product. In this sense, requirements can be considered the translation of needs into product design specifications, which define the set of technical constraints that make it possible to assess whether needs are satisfied in a given context. According this view, once a target need has been identified, the formulation of the related requirements is an essential design activity that implies a composite combination of analysis, synthesis and choice [41].

Regarding the tools and the methods for need identification and requirement definition, a number of approaches have been proposed in the Engineering Design literature and are implemented in industry (for a survey, readers can refer to [42]). Quality Function Deployment is probably the most popular [43], others aim at including users' inputs in the design process, such as value-centered approaches and user/human-centered methods (e.g., [44,45], for a review, [37]), while other methods – such as Value Engineering and target pricing and costing – can also play a role [20].

In particular, some contributions have proposed detailed prescriptive criteria to codify the information gathered from external sources [46], some others have attempted to support requirements elicitation through dialog-based computer systems [47], and others have implemented virtualization of interaction tests [48], including the users' 'life space' with cultural aspects and usage contexts [49].

However, all these methods focus on needs and associated requirements with reference to "product use", and therefore concern product functionalities. Being successful innovation associated to many different situations and stakeholders, all these needs have to be adequately addressed [50] and "beyond-use" situations have to be carefully studied, as discussed in the next section. Besides, after introducing the concept of a multi-actorial context, the paper continues with an original model developed by the authors to build a suitable design specification (list of requirements and related links to the different stakeholders' needs). The resulting model is an adaptation of concepts already established in other domains, specifically strategic analyses and negotiations. Nevertheless, its reliability for the specific purpose of supporting design for innovation should be demonstrated by multiple applications in real case studies. While this extensive validation is still in progress, the last chapter of the paper before the conclusions describes in detail an application in industry that provides a comprehensive picture of the applicability of the proposed model and of the value of its outcomes.

3. Beyond-use situations and the multi-actorial context

The process leading to innovation is considerably more complicated than making sure that an individual buyer and seller will find mutual benefit from a transaction, so that the former will buy products from the latter [51]. In fact, the process that leads to the purchasing decision depends on the organizational complexity of the customer (who may be an individual, a household, a small firm or a very large organization) and on the mutual influence between actors. This mutual influence, based on social and organizational pressure, word-of-mouth effects [52] and externalities [53] is known to be a key determinant in innovation diffusion processes, so that an innovation is seldom associated to a single actor [51,54]. Moreover, not only customers and users are not necessarily the same person, but even benefits of a product might derive not only from the mere use [19,55] and designers often experience that different stakeholders are involved and influence the use of the product [18,56].

Therefore, in order to frame this problem in a systematic way, as shown in Fig. 1, three main "beyond use" situations can be imagined [57]. The first one is "purchasing", which is directly done by customers. The second one is "delivering benefits" which is associated to, but not coincident with, usage (e.g., the doctor uses a medical device and the patient benefits from it). The third situation is "creating further impact or externalities", that considers the effects that propagate beyond direct beneficiaries (e.g., inconve-nience for passengers if the underground is continuously out of order).

Given these three situations, it is possible to identify four stakeholder roles: buyers (typically appointed as customers), users, beneficiaries and outsiders. The three former categories are directly involved in the adoption process, while the last one rarely exerts a direct influence on it.

Obviously, the proposed set of situations and stakeholder roles represent a good balance between simplicity and capability to characterize realistic situations. Of course, there might be cases that are more complex so that the model might have to be extended, e.g., defining diverse categories of outsiders. As well, there are simpler situations in which a single actor plays more than one role at once. In any case, these situations do not substantially affect the term of the discussion.

Each stakeholder involved in the process operates according to a set of specific needs. These needs can emerge from the actor itself

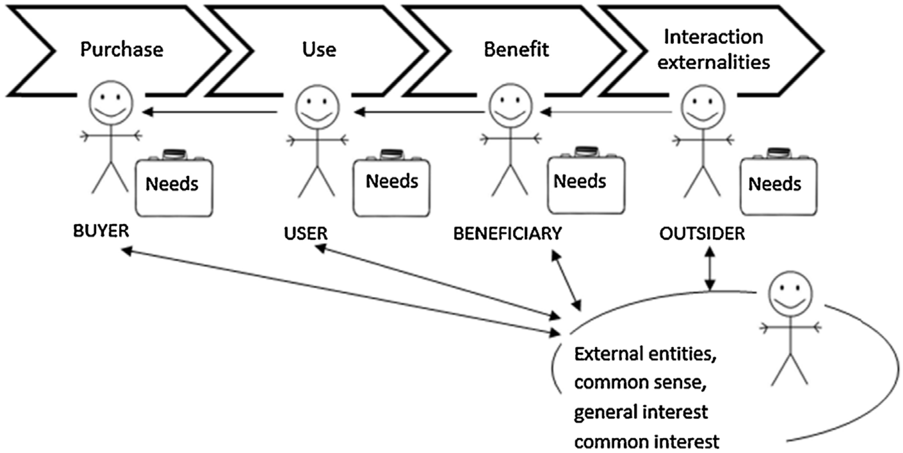


Fig. 1. The multi actor context of beyond use situations.

or can result because of influences cast among actors. Actors in fact are immersed in social contexts and the relationships between them influence their opinions and needs. A new medical device very cheap, but somehow difficult to use, will be probably discarded, because doctors will object to the procurement office of the hospital and oppose the purchasing decision, or may simply avoid using it once it has been bought. Conversely, a nurse that uses a bandage for a daily medication can convince the doctor of the validity of that product with respect to others, as well as the maintenance crew of bus vehicles can stress designers for the use of specific components in the architecture. In these cases, actors might change their own opinion due to the exerted influence.

In some cases, the relationships between all these actors are relatively straightforward to identify, because of organizational or contractual linkages. In other cases, they may be more subtle and lead to indirect impacts and externalities. Some needs may be well known, either because they are obvious, or because they are induced by external entities (e.g., regulations), or because they reflect common sense or general interest. In other cases, needs may be more or less hidden and sometimes even unknown to the same actors. Referring to the medical devices example, it is obvious to assume that – all the rest being equal – hospital management will prefer a product that minimizes discomfort to the patient, even without receiving direct influence from patients themselves. However, the importance that management will attach to this need may be altered if patients do cast such an influence (e.g., through a patients-rights association) or if – by purchasing a less invasive device - managers consider that this choice might attract a higher number of patients.

All this has two main consequences for product development. First, designers must consider a wider set of needs deriving from multiple stakeholders as the basis for requirements definition. Requirements must take into account these stakeholder needs in such a way that all stakeholders, who are involved in the adoption decision, find an equilibrium in the product features.

The second consequence is that product developers should investigate the relationships and the mutual influences among actors, to estimate how importance of the needs is attributed and can be modified. Knowing in fact the actual importance attributed is indeed of paramount importance for any product requirement definition and is integral to defining the "go-to-market" strategy to be followed for ensuring its introduction.

In the following, hence, we will refer to two classes of needs, "native needs" and "reported needs". Needs are native if they are of direct concern to the actor itself, while an actor X has a reported need Y, if that need emerges because of the influence cast by some other actors on X, and if Y would not have been considered at all by X, had the influence been missing.

4. From needs to requirements: how to manage multi-stakeholder contexts

The approach here proposed for the analysis of inter-actor influences is inspired by social influence network models [58] and by the Multi-issue Actor Strategy Analysis Model [59]. Both these approaches are usually applied to strategic analyses and negotiation problems. They assume that an actor's present opinion on an issue results from the combination of that actor's original opinion and from the influences that other actors have exerted on him or her. Besides, they model this influence in different ways. Friedkin and Johnsen, in particular, that derive their background from social psychological theories [60,61] set their work onto the Social Network Theory [62–65] and consider that the degree with which an actor will be influenced depends on his or her *susceptibility* to interpersonal influences, which weights the part of the actor's opinion that results from external influences.

On the other hand, the MASAM approach that derives from political forecasting (e.g., [66]), collective decision-making [67] and negotiation support [68], borrows from these backgrounds a set of constructs (and the associated metrics). This allows defining actor's opinion, and specifically the *position* of that actor on the *issue* and the *salience* (i.e., the relevance) of that issue to him or her.

Susceptibility and salience may be correlated, but they are consequent. In some cases, an actor who considers an issue as very relevant to him or her may be open to external influences. In other cases, this high degree of relevance may lead to being inflexible about it. Therefore, it is interesting to investigate how issues are positioned with respect to these two aspects, as shown in Fig. 2.

If the salience of i on an issue j (i.e., $Sal_{i,j}$) is high, the actor is highly interested and may be more or less prone to be influenced. If the own susceptibility of an actor i about the issue j (i.e., $a_{ii,j}$) is high, there will be room for negotiation. Instead, if susceptibility is low, the actor will not be open to changes in his or her opinion. If salience on an issue is low, a subject will be uninterested. In case of high susceptibility, the actor will be very open to external influence since the issue is not be a concern at all; conversely, the actor may have low interest in the issue, but also be closed to external influence, and the issue will not be touched.

In our model, the issues on which actors focus their attention are the needs.

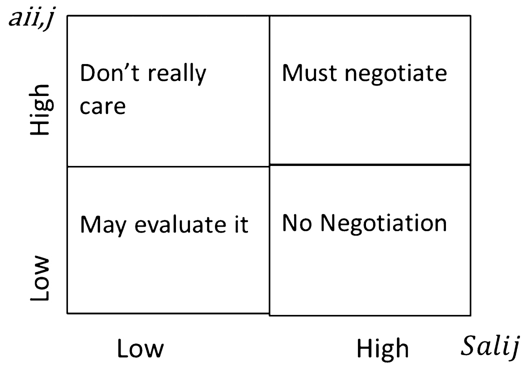


Fig. 2. Salience and susceptibility define four situations for negotiation.

4.1. Native needs

Given a certain need, the preferred outcome, which, if realized, would best suit the actor's objectives, is defined as the *position* of that actor on the need [59]. This means that, given a certain need manifested by a certain actor (e.g., weight of a medical device for ensuring its stability), other actors might have completely different opinions (e.g., a lighter device might be easier to handle for cleaning purposes). The position indicates the direction toward which an actor perceives an identified need with respect to his own expectations. In this study, the position of Actor i on Need j, $pos_{i,j}$, is set along a continuum between two extreme values that can be normalized to the interval [−1,1], so that $-1 \leq pos_{ij} \leq 1$.

Actors can prioritize their positions on each issue, and this priority can be estimated as the degree of salience [59]. Salience represents the degree with which the realization of the favorable outcome is relevant to the actor's overall objectives. In this study, the salience $sal_{i,j}$ of Actor i on Issue j represents the degree with which the actor feels the need as a priority, and the weight with which he or she would perceive a loss of utility should the outcome differ from the preferred position. Salience can be normalized into the [0,1] interval, so that salience of 0 means that the actor has absolutely no interest in the need, whereas the value 1 represents the strongest possible salience. A need j will be considered to be native to actor i if and only if sal_{ij} is non-zero.

Position and salience provide a complete definition of the opinion of Actor i on Need j, and make it possible to define the importance $imp_{i,j}$ attributed by actors to their native needs. In the absence of influence, importance would be given by the product of position and salience.

$$imp_{ij} = sal_{ij} * pos_{ij} \tag{1}$$

So, if an actor i who has $pos_{i,j} = -0.5$ and $sal_{i,j} = 0.2$ on need j, will have a weak interest for a preferred outcome that is slightly oriented to negative values. This will result in $imp_{ij} = -0.1$. Two actors may perceive need j with the same salience, but have opposite positions on them, which will lead to a conflict to be managed in some way.

4.2. Reported needs

Actors also have the attitude and capability to influence other actors. The influence process can be modeled by adopting the following three assumptions made by Friedkin and Johnsen [59] when defining the degree of potential influence $inf_{i',i,j}$ (the influence that actor i might undergo due to actor i' with respect to issue j). This influence:

- is set along a linear continuum between 0 and 1, and hence:

$$0 \leq inf_{i',i,j} \leq 1 \quad \forall i, \forall i', \forall j \tag{2}$$

- is such that the total influence cast by other actors is either nil, or equal to 1[1]:

$$\sum_{i' \neq i} inf_{i',i,j} = \begin{cases} 1 & \text{if } inf_{i',i,j} > 0 \text{ for at least one value of } i' \\ 0 & \text{otherwise.} \end{cases} \quad \forall i, \forall i', \forall j \tag{3}$$

- is such that reflexive influences are nil.

$$inf_{i,i,j} = 0 \quad \forall i, \forall j \tag{4}$$

- So, it is possible to construct the $N \times N$ matrix of *potential* direct influences among the N actors on the issue j, defined as:

$$\overline{\overline{inf_j}} = [inf_{i',i}]_j \quad \forall j \tag{5}$$

Given these potential influences and depending on the openness of each actor to accept them, opinions on needs will be modified, altering the importance ascribed to native needs and perceiving new ones. The influence process is characterized by the following:

- If the influence between two actors exists (i.e., if $inf_{i',i,j} > 0$), the *susceptibility* of actor i to interpersonal influence on the issue j, $a_{ii,j}$, mitigates the influence he or she can be subject to. Susceptibility may assume any value along a linear continuum between 0 and 1, and hence:

$$0 < a_{ii,j} \leq 1 \quad \forall i, \forall j \tag{6}$$

If there is no influence, $\sum_{i' \neq i} inf_{i',i,j} = 0 \ \forall i, \forall j,\ a_{ii,j}$ is assumed to be zero.

- At each occasion in which influence among actors occurs, potential influences become effective if actors are susceptible to receive them. So, a new matrix that describes the *effective* influences is determined:

$$\overline{\overline{INF_j}} = A * \overline{\overline{inf_j}} + I - A \quad \forall j \tag{7}$$

where $A = diag(a_{11}, a_{22}, \ldots, a_{NN})$ is the $N \times N$ diagonal matrix of actors' susceptibilities to interpersonal influences. Therefore, the effective influence an actor is subject to is given by a blend of potential external influences (weighted by his or her susceptibilities) and internal conviction (given by the complement to 1 of susceptibilities). Consequently, the matrix described by Eq. (7) is such that:

(1) the elements of the main diagonal represent the internal conviction of an actor:

$$INF_{ii,j} = 1 - a_{ii,j} \quad \forall i, \forall j \tag{8}$$

(2) the other elements of the matrix are:

$$INF_{i',i,j} = a_{ii,j} * inf_{i'i,j} \quad \forall i \ con\, i' \neq i, \forall j \tag{9}$$

and represent the external influences, moderated by susceptibilities.

- The influence process progresses over time and is iterative. Therefore, the opinion an actor has at time t will depend on his/

[1] It is worth noting that the influence potentially exerted by all the other actors is here appointed as a binary variable: it assumes the value 1 if at least one of the actors has the capability to influence the actor i (i.e. the relative influences have to be normalized); the value is instead zero if there are no actors in the condition to influence the actor i. Besides, the susceptibility is the parameter that controls the individual permeability to others' influences.

her opinion in the past. Again, the degree with which one's opinion varies at each step will depend on susceptibilities. Considering a group of N actors, the influence process is therefore defined through:

$(10)\overline{IMP_j^{(t)}} = (I-A)*\overline{IMP_j^{(1)}} + A*\overline{\overline{INF_j}}*\overline{IMP_j^{(t-1)}}$ where $IMP^{(1)}$ is the $N \times 1$ vector of initial importance attributed by the N actors, $IMP^{(t)}$ is the $N \times 1$ vector of importance values at step t, $INF_j = [INF_{i',i}]_j$ is the $N \times N$ matrix of the real influences on need j, and A is the matrix of susceptibilities. If an actor is not susceptible to external influence, the importance vector will remain the same, whereas change in opinions will be faster if susceptibility is high.

Assuming that the influence process reaches an equilibrium, that is

$$\exists \ \lim_{t\to\infty} \overline{IMP_j^{(t)}} = \overline{IMP_j^{(\infty)}} \quad \forall j \tag{11}$$

Eq. (10) becomes:

$$\overline{IMP_j^{(\infty)}} = (I-\overline{\overline{A}})\overline{IMP_j^{(1)}} + \overline{\overline{A}}*\overline{\overline{INF_j}}*\overline{IMP_j^{(\infty)}} \tag{12}$$

and hence:

$$\overline{IMP_j^{(\infty)}} = (I-\overline{\overline{A}}*\overline{\overline{INF_j}})^{-1}(I-\overline{\overline{A}})*\overline{IMP_j^{(1)}} \quad \forall j \tag{13}$$

Having determined the final importance of each need and for each actor (represented by the elements of $\overline{IMP_j^{(\infty)}}$) is a key step in the direction of creating a comprehensive list of requirements aggregating the views of different actors. In fact, the final goal of this analysis can be the compilation of a single list of requirements that may – for instance – be used as an input to a QFD matrix.

The aggregation of needs across actors is quite critical, since it would be misleading to simply compute an average of importance levels. This would "cover up" the potentially contrasting views that actors may have on a given need, and would lead to developing a product that does not really satisfy any specific actor, would easily be vetoed by one or more of them, and therefore would not be adopted at all.

Moreover, products are seldom adopted by having all actors meeting together, so that they can negotiate over their contrasting views. In real life, the sales and adoption process often is based on a number of bilateral interactions between the producer and each actor, *all* of which must lead to a positive outcome for the adoption process to advance. So, analyzing actor-specific importance vectors allows the firm to understand potential conflicts, design the sales process and, if needed, try to modify the inter-actor pattern of influences in order to reduce resistance to adoption.

That said, the product development team might nonetheless find it appropriate to transform vectors IMPi (∞) into a single

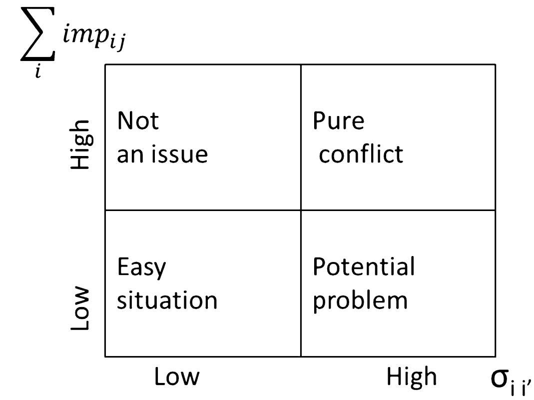


Fig. 3. Discord and overall importance distinguish four situations of conflict between i and i'.

vector IMP (∞) that may be fed into a QFD matrix. When doing so, it is important to identify conflicts, which occur if two actors i' and i have, with respect to need j:

$$IMP_{i',j}^{\infty} * IMP_{i,j}^{\infty} < 0 \tag{14}$$

So, an indicator of the degree of potential conflict arising around the product is represented by a measure of the *discord* between each pair of actors, given by:

$$\sigma_{i'i} = \frac{IMP_{i',j}^{\infty} - IMP_{i,j}^{\infty}}{sign(IMP_{i',j}^{\infty}) * sign(IMP_{i,j}^{\infty})} \tag{15}$$

Being

$$IMP_{i',j}^{\infty} = max_k IMP_{k,j}^{\infty} \quad \text{and} \quad IMP_{i,j}^{\infty} = min_k IMP_{k,j}^{\infty}.$$

Having now the information about conflicts, designers can consider it in addition to an aggregated measure of importance as the one expressed by Eq. (16):

$$Imp_j = \sum_i imp_{i,j}^{\infty} \tag{16}$$

This allows framing the problem need by need, and distinguishing among the four cases shown in Fig. 3.

A first case occurs if a need is not very important and actors are substantially in agreement, which suggests that there hardly will be any concern. A second case emerges in the case of needs that are considered by all parties to be important and do not exhibit conflicts; meeting these needs will obviously become a priority for the product development team. In the latter two cases, actors exhibit a significant disagreement on a need. Should the importance be low, the potential conflict will be easy to solve,

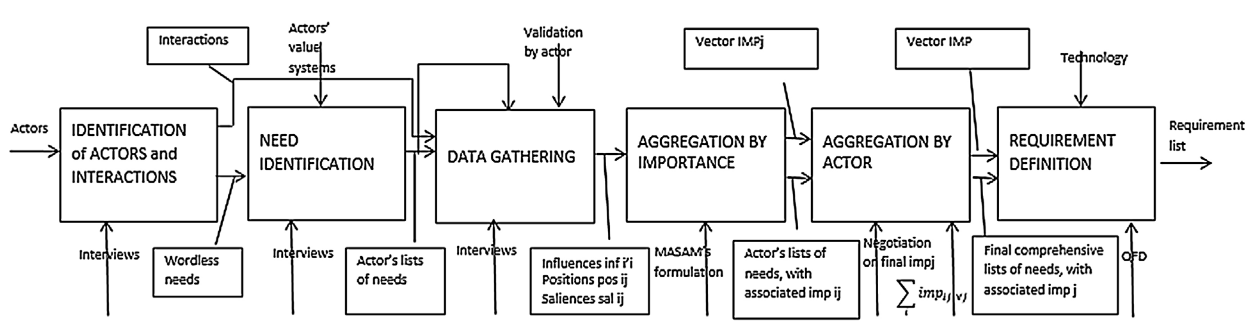


Fig. 4. The complete procedure for the multi-stakeholder analysis. The meaning of the arrows is compliant with IDEF0 modeling.

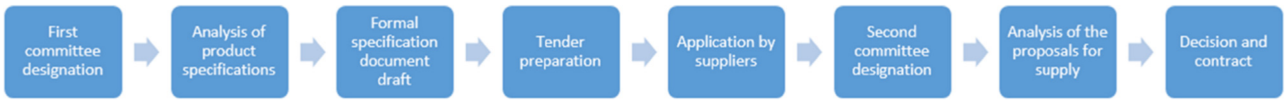


Fig. 5. The procurement process in the wards.

	Purchaising DPT	Pos ij	Sal ij	impij (1)	aii, j	Who? i'	Pos i'	Sal i'	infi'i
1	cheapness	1	1	1	0				
	Management	**Pos ij**	**Sal ij**	**impij (1)**	**aii, j**	**Who? i'**	**Pos i'**	**Sal i'**	**infi'i**
2	reduce length of hospital stay	1	0,8	0,8	0,6	Doctor	1	0,6	1
3	reduce human resources	1	0,75	0,75	0,8	Doctor	1	0,65	1
	Doctor	**Pos ij**	**Sal ij**	**impij (1)**	**aii, j**	**Who? i'**	**Pos i'**	**Sal i'**	**infi'i**
2	reduce healing time (reduce length of hospital stay)	1	0,65	0,65	0,6	Management	1	0,8	0,5
						Patient	1	0,8	0,5
3	reduce human resources	1	0,6	0,6	0,5	Management	1	0,75	1
4	effectiveness of treatment (in situ pharmacological pr	1	1	1	0				
5	prevent losses and bleeding	1	0,8	0,8	0,4	Nurse	1	0,8	0,4
						Patient	1	0,6	0,6
6	reduce infection risk	1	0,9	0,9	0,4	Nurse	1	0,7	1
7	simplify further analysis	1	0,6	0,6	0,6	Nurse	1	0,8	1
8	feels comfortable (not annoying)	1	0,7	0,7	0,4	Nurse	1	0,7	0,3
				0		Patient	1	1	0,7
9	pain relief	1	0,75	0,75	0,5	Patient	1	1	1
10	correct positioning and adherence	-0,6	0,25	-0,15	0,6	Nurse	1	0,9	1
11	breathable	1	1	1	0,5	Nurse	1	0,9	1
12	good resistence if soaked	1	0,3	0,3	0,8	Nurse	1	0,7	0,5
				0		Patient	1	0,6	0,5
13	easy to apply and remove	1	0	0	0,3	Nurse	1	1	0,55
				0		Patient	1	0,65	0,45
14	fast application	1	0	0	0,3	Nurse	1	1	0,45
				0		Patient	1	0,6	0,55
15	ensure long effectiveness	1	0	0	0,45	Nurse	1	0,65	1
18	encurage good cicatrization	1	0	0	0,8	Patient	1	1	1
17	adapt to different body parts	1	0	0	0,5	Nurse	1	1	1
	Nurse	**Pos ij**	**Sal ij**	**impij (1)**	**aii, j**	**Who? i'**	**Pos i'**	**Sal i'**	**infi'i**
5	prevent losses and bleeding	1	0,8	0,8	0,5	Doctor	1	0,8	0,6
				0		Patient	1	0,6	0,4
6	reduce infection risk	1	0,7	0,7	0,5	Doctor	1	0,9	1
7	simplify further analysis	1	0,8	0,8	0,8	Doctor	1	0,6	1
13	easy to apply and remove	1	1	1	0,8	Patient	1	0,65	1
14	fast application	1	1	1	0,8	Patient	1	0,6	1
15	ensure long effectiveness	1	0,65	0,65	0				
8	feels comfortable (not annoying)	1	0,7	0,7	0,6	Patient	1	1	1
16	allow to use wrong dimensions	1	0,4	0,4	0				
9	pain relief	1	0,7	0,7	0,5	Patient	1	1	1
17	adapt to different body parts	1	1	1	0				
12	good resistence if soaked	1	0,6	0,6	0				
11	breathable	1	0,9	0,9	0,3	Doctor	1	1	1
10	correct positioning and adherence	1	0,9	0,9	0,4	Doctor	-0,6	0,25	1
4	effectiveness of treatment	1	0,6	0,6	0,4	Doctor	1	1	1
2	reduce healing time	1	0	0	0,3	Doctor	1	0,6	1
18	encurage good cicatrization	1	0	0	0,5	Patient	1	1	1
	Patient	**Pos ij**	**Sal ij**	**impij (1)**	**aii, j**	**Who? i'**	**Pos i'**	**Sal i'**	**infi'i**
2	reduce length of hospital stay	1	0,8	0,8	0				
5	prevent losses and bleeding	1	0,6	0,6	0				
13	easy to apply and remove	1	0,65	0,65	0,8	Nurse	1	1	1
14	fast application	1	0,6	0,6	0,8	Nurse	1	1	1
8	feels comfortable (not annoying)	1	1	1	0				
18	encurage good cicatrization	1	1	1	0				
9	pain relief	1	1	1	0				
12	good resistence if soaked	1	0,5	0,5	0				

Fig. 6. Matrix of the native attributes.

at the limit by neglecting the need and downplaying the conflict when engaging with actors. Conversely, should the importance be high, the product development team will have to find ways for tackling what could become a very critical stumbling block for product success. Ideally, one would like all stakeholders to meet together and negotiate a compromise solution. However, it may be quite common to find cases in which this direct confrontation is not possible, and a compromise solution being imagined by the development team could simply be vetoed by any one actor. So, the firm will be forced to choose one of two paths. On the technical side, the firm could try to conceive technical solutions that remove the blocking contradictions [61]. On the side of marketing, it could try operating on the actors' preference structure by either acting on individual actors (e.g., convincing a hospital manager that a less painful treatment may ultimately attract patients and increase revenues) or on inter-actor influences (e.g., stimulating the bus drivers' trade union to take a firm stance on the issue of driving comfort).

Once importance values are aggregated and eventual conflicts managed, each need will have its well-identified importance and, consequently, the list of needs will be ready to be fed in a QFD matrix. This last step is common practice and does not therefore need to be discussed further.

Summing up, one can describe the complete procedure through the diagram shown in Fig. 4, whose symbolical representation is partially borrowed from IDEF0 diagrams.

5. A case from the medical-care industry

The multi-stakeholder method presented in this paper has been progressively developed and tested in a variety of cases [69], from industrial machinery to medical devices. Those pilot experiences have been supported by a prototype spreadsheet application under the guidance of one of the authors acting as a facilitator.

In this paper we will describe one of these cases, coming from an Italian start-up company that develops an innovative product (KITOSMART®) that could replace the bandages, gauzes and dressings used to dress wounds in both domestic and hospital environments.

Working with a start-up company in the Medtech industry was an ideal test-bed for the method. Being a start-up, the firm really felt the need to make sure its products could be well received by the market. Organizational procedures and processes were not structured yet, and there was no inertia in adopting a new method for requirements capture. Moreover, the acceptance of medical devices does not only depend on the technical merits of the product, but also on the firm's capability to understand and interact with a complex purchasing process that includes multiple actors.

At first, the firm analyzed the purchasing decision process in detail, which appeared to be well-structured and completely defined. When a supply contract for dressings expires, the purchasing department appoints a committee of doctors and nurses, who compile a written document defining the specifications that the dressing must satisfy. The specifications are then inserted in a tender document to which companies can apply. Firms are required to send specimens of their products, which are tested by another committee in charge of shortlisting the preferred ones. At this point, the purchasing department decides the product to buy, based on "economic convenience" and negotiates a 3–5 year contract. The complete decision process is represented in the diagram of Fig. 5.

Within this process, the firm identified and interviewed the following five actors: the purchasing department, ward management, doctors, nurses and patients. Interviews were carried out on 20 individuals in 5 different hospitals, with sufficient experience and leadership roles. Doctors were plastic surgeons and operating in departments specialized in severe burns; nurses were mostly head nurses and/or experts in applying bandages on bedsores and burns. Almost all doctors and nurses had been included at least once in a committee for the evaluation of bandages and dressings. It was chosen not to include patients' relatives, since their needs were almost the same as patients' and they were recognized to be detached from the decisional process.

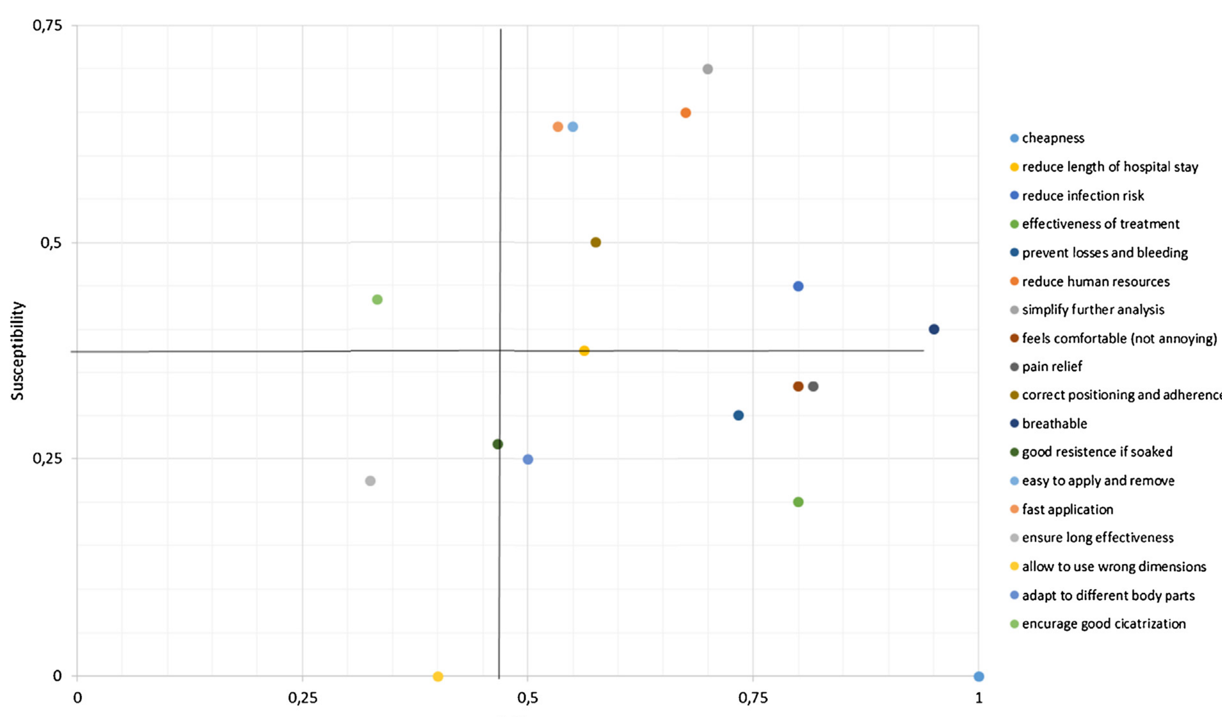


Fig. 7. Analysis of negotiable needs.

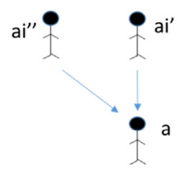
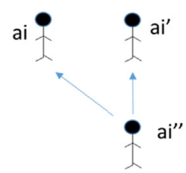
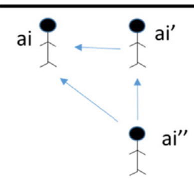
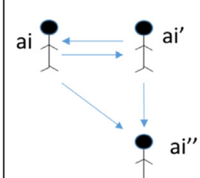
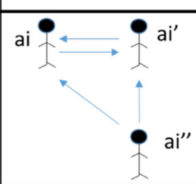
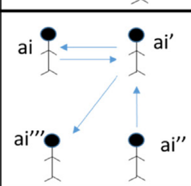
Cases	Morfology	Occurence	need	actor	imp (1)	Imp (∞)
1		It occurs for needs 4, 15, 17: from N to D	4	D	1,00	0,79
				N	0,60	0,60
			15	N	0,65	0,65
				D	0,00	0,17
			17	N	1,00	1,00
				D	0,00	0,33
2		It occurs for need 3: between M and D It occurs for needs 6, 7, 10, 11: between D and N	3	M	0,75	0,65
				D	0,60	0,62
			6	N	0,70	0,76
				D	0,90	0,87
			7	N	0,80	0,71
				D	0,60	0,65
			10	N	0,90	0,77
				D	-0,15	0,29
			11	N	0,90	0,91
				D	1,00	0,97
3		It occurs for need 12: N and P influence D	12	D	0,30	0,49
				N	0,60	0,60
				P	0,50	0,50
4		It occurs for need 9, 18: P influences N and D	9	D	0,75	0,83
				N	0,70	0,80
				P	1,00	1,00
			18	D	0,00	0,76
				N	0,00	0,33
				P	1,00	1,00
5		It occurs for need 8: P influences N and D, as well N influences D	8	D	0,70	0,75
				N	0,70	0,84
				P	1,00	1,00
6		It occurs for needs 13, 14: P and N have a reciprocal influences and then both of them influence D	13	D	0,00	0,09
				N	1,00	0,85
				P	0,65	0,80
			14	D	0,00	0,09
				N	1,00	0,83
				P	0,60	0,77
7		It occurs for need 5: D and N have a reciprocal influence but both of them are influenced by P	5	D	0,80	0,77
				N	0,80	0,77
				P	0,60	0,60
8		It occurs for need 2: D and M have a reciprocal influence, but D influences also N and is influenced by P	2	M	0,75	0,76
				D	0,70	0,71
				N	0,06	0,08
				P	0,80	0,80

Fig. 8. Influence analysis of Needs for CHITOSMART products.

Interviews were composed by two different sections: initially, a semi-structured interview was aimed at identifying potential needs and the influences between actors; then, a structured interview allowed to elicit values for position, salience and susceptibility to the needs. Each item was calculated directly asking people to locate themselves on the scales that represented the constructs. The values attributed were validated through expressed sentences on a 5-level Likert scale, wherein the value '0' corresponds to a neutral position between a strong disagreement ('−2') and a strong agreement ('+2'). Internal consistency of the measures was checked using Cronbach's alpha.

The collected data are listed in Fig. 6. It is noteworthy that positions on needs were equal to 1 in all cases except for one (i.e., need 10). In this case, doctors had a quite different opinion than nurses, since "adherence to body portions" is important to maintain the medication steady, but it can compromise breathability.

At first, data were used to map needs according to the scheme in Fig. 2. As shown in Fig. 7, some needs resulted to be "not negotiable" and others as issues of possible concern. Among the nonnegotiable needs, some were straightforward and highly relevant from the medical perspective (e.g., shortening the cicatrizing process), while others were relevant from both the medical and managerial points of view (e.g., shortening hospital stay). Need 10 came out to be "negotiable", and this made the designers hope that the conflict could be easy to tackle later on.

The second step of the study consisted in analyzing inter-actor influences on the needs. The results of the analysis are shown in Fig. 8.

At this point, the firm attempted to aggregate importance across actors. The only conflict that had emerged, between adherence to body portions and breathability, was solved by tackling the contradiction from a technical perspective. Specifically, the product development team designed pre-shaped bandaging components, thus ensuring stability, and revised the structure of the bandage in order to allow a better modulation of compression. For the other needs that were conflict-free, merging the different lists of needs in a single one was performed without any particular problem. In the end, a final list of needs was drafted, and Fig. 9b shows the final table that was accepted by the firm and then definitively validated by the panel of experts interviewed.

Comparing the list of needs identified thanks to this method (Fig. 9b) to the original list of needs developed only basing on designers' experience (Fig. 9a), one can observe that the latter list is richer than the former, and that the importance attributed to the needs have changed. Some needs were fairly obvious and hence were identified since the beginning, but other ones emerged only because of the direct investigation of the multi-actorial process. For instance, shortening the air exposure of the injured body areas was an obvious need and represented a key element of the product's value proposition, because it reduces the leads to low risks of infection and goes hand in hand with a quicker and cheaper procedure, ease of positioning and use, faster medical treatment. Other requirements, such as the anatomic pre-conformation of the components, the modulation of compression that hinders potential bleedings and blood-serum storage over the wound, the possibility of in situ pharmacological preparations and medicaments, and the impact on medical personnel's efficiency emerged because the analysis of multiple actors' perspectives. Moreover, a new need that was identified allowed to prevent a conflict (the one between breathability and adherence) and also led to a technically innovative solution.

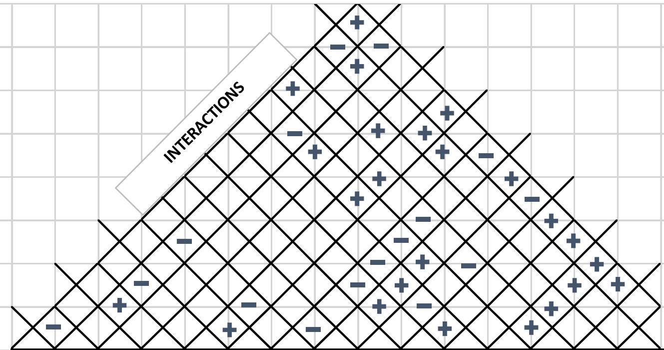
Moreover, values of importance were modified following the study of inter-actor influences, which shows that a simple aggregation of a customer firm as a single entity might be misleading. The producer benefitted by gaining a much deeper understanding of which needs were (natively or reportedly) more important to each actor, thus defining with greater precision the message to be delivered to each actor when marketing the product.

Fig. 10 shows the derived house of quality for the QFD procedure. It has to be stressed that, in this house of quality, the importance associated to requirements do not reflect an abstract view of a "customer", but the precise and structured interplay of the actors that are involved in the innovation diffusion process.

id	description	impij	id	description	impij (∞)
1	Cheapness	1,00	1	Cheapness	1,00
2	Reduce length ofhospital stay	0,80	2	Reduce length ofhospital stay	0,59
			3	Reduce human resources	0,63
			4	Effectiveness of treatment (in situ pharmacological preparations)	0,69
5	Prevent losses and bleeding	0,71	5	Prevent losses and bleeding	0,71
6	Reduce infection risk	0,81	6	Reduce infection risk	0,81
			7	Simplifyfurther analysis	0,68
8	Feels comfortable (not annoying)	0,87	8	Feels comfortable (not annoying)	0,87
9	Pain relief	0,88	9	Pain relief	0,88
10	Correct positioning and adherence	0,53	10	Correct positioningand adherence	0,53
11	Breathable	0,60	11	Breathable	0,94
12	Good resistence if soaked	0,20	12	Good resistence ifsoaked	0,53
13	Easyto applyand remove	0,60	13	Easyto applyandremove	0,58
14	Fast application	0,50	14	Fast application	0,56
15	Ensure longeffectiveness	0,60	15	Ensure longeffectiveness	0,41
			16	Allowto use wrongdimensions	0,40
			17	Adapt to different bodyparts	0,67
18	Encurage good cicatrization	0,70	18	Encurage good cicatrization	0,70

(a) (b)

Fig. 9. Final list of requirements.



	CUSTOMER'S ATTRIBUTES	TECHNICAL SPECIFICATIONS	non adhesive and soft	stretch	traction resistent	open and enveloping	anatomically structured	variability of sizes and dimensions	water vapor permeable	impermeable to biological fluids	radiolucent and nonmagnetic	hypoallergenic and inert	sterile	internal medicament	temperature homeostasis	interconnection by velcro	compressive	number of relations
1	Cheapness	1,00		●			◊	○	●	●	○							6
2	Reduce length of hospital stay	0,59				◊	◊				○						●	4
3	Reduce human resources	0,63				◊			●	●		●	●	○		○		7
4	Effectiveness of treatment (in situ pharmacological preparations)	0,69		●	●	○	●	●						●		○	○	8
5	Prevent losses and bleeding	0,71	●	●	●	◊	◊	◊	●	●		●	●	○	●	◊	●	14
6	Reduce infection risk	0,81	○			●	●		○	○		○	●	◊	◊		○	10
7	Simplify further analysis	0,68		○	○		◊			●	○		○			○	○	8
8	Feels comfortable (not annoying)	0,87	●	●	◊	●	●	○	○			●		◊		●		10
9	Pain relief	0,88	●	○		○	●	○				●	○	○		●	○	10
10	Correct positioning and adherence	0,53	●	○	◊	○	●	○	◊	●							○	9
11	Breathable	0,94	●			○	○		●	●		●	●	○	○	○	●	11
12	Good resistence if soaked	0,53		◊	◊	◊			●	●		●	●	○			◊	9
13	Easy to apply and remove	0,58	○	○	○	●	○	○			○			○		○		9
14	Fast application	0,56	○	○	○	●	○	○								●		7
15	Ensure long effectiveness	0,41		●	●	◊	●	●								◊	◊	7
16	Allow to use wrong dimensions	0,40		●	●		○		◊	◊		◊		●	◊		●	9
17	Adapt to different body parts	0,67	●			○	○	●						●				5
18	Encurage good cicatrization	0,70	○				◊		●	●		●	●		◊		○	
	Technical Importance by ISM		49,3	47	27,4	39,4	50,9	29,9	46,6	54,3	8,54	50,1	43,6	30,3	11,1	32,5	37,6	
	Relative Tecnical Importance by ISM		90,7	86,5	50,4	72,5	93,6	55,1	85,7	100	15,7	92,3	80,2	55,8	20,5	59,8	69,2	
	Ranking Tecnical features by ISM		4	5	13	8	2	12	6	1	15	3	7	11	14	10	9	

Fig. 10. House of quality.

6. Conclusions

The paper aims at contributing to the debate about needs identification and requirements specification, by introducing an explicit representation of different stakeholders' needs and their reciprocal influences in these activities. The rationale behind the method is that – failing to do so – products will be designed quite narrowly around the perspective of a single stakeholder. Apart from products characterized by a very simple purchasing process, a product will be able to successfully penetrate the market only if all relevant stakeholders agree on its adoption. So, mapping needs and formulating requirements with a robust and comprehensive approach can be essential for ensuring successful innovation diffusion processes.

The paper has described a new methodology for the analysis of needs from a multi-stakeholder perspective by examining the impact of inter-actor influence. The methodology has been tested in several instances through a prototype implementation in a spreadsheet, and the paper reports the case of an Italian start-up company in the medical devices industry. Results obtained have been very interesting and allowed the firm to develop a set of products that were quickly accepted for a distribution partnership by an established industry player.

Due to the innovative nature of the methodology, further refinements are of course possible. As well, its integration within a software tool suitable to guide the user in the proper application of the methodology is an obvious development of the work here proposed.

Furthermore, based on experience gained when using it in practical cases, one main direction for further research lies in the systematic development of ways to manage conflicts in the adoption process. As mentioned, this implies both working on technical features, in order to sidestep contradictions, and on the sales process, in order to operate on actors' perceptions and their mutual influences.

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