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A METHODOLOGICAL TOOLKIT TO SUPPORT INNOVATION PROCESSES IN INDUSTRY

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A methodological toolkit to support innovation processes in industry

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To the memory of a great innovator who died during the drafting of the thesis, President Nelson Mandela.
To all the people fighting for justice to innovate the world like he did.

Abstract

The aim of this PhD thesis is to propose an original set of methodologies and tools, viable to support innovation processes in industrial environments. The thesis benefits from an insightful research about current industrial practices and highlights the reasons that have hindered a wide diffusion of design tools developed in academia.

The context of the work is clarified in the first Section, which illustrates the main fields of the work within the general framework of innovative engineering design. The candidate has identified two particular circumstances requiring major research attention. On the one hand, firms can face situations in which innovation is perceived as a compelling need, but the directions on which to invest have not been chosen. In this case, a thorough analysis of industrial processes is proposed that allows individuating business areas needing major re-engineering efforts. On the other hand, managers and R&D fellows have skipped any careful analysis and conceived new products to be developed, but limited resources do not allow the complete design of all the alternatives. In this case, a suitable decision support method is proposed, viable to guide towards the most profitable option.

The problems encountered in the first situation are treated in the second Section of the thesis. This part of the manuscript shows an integrated model for the redesign of products and processes. The tools belonging to the initial framework have been further developed in order to better meet the exigencies of industrial subjects.

Besides, the third Section is devoted to shed light on the contribution of the candidate in the field of decision making. The final proposal stems from various investigations about the factors mostly influencing customer perceived satisfaction and the success of new product development initiatives.

The fourth Section concludes the thesis, underlining the obtained results and their main limitations.

Contents

1 Introduction

Engineering designers envision their discipline as a key activity linking manifold research areas. More specifically, engineering design is somehow devoted to translate human needs into technical solutions. In this sense, a representation is quite diffused and acknowledged (at least in the field) that places the work of engineering designers at the intersection of streams of disciplines varying according to their cultural and technical content (Fig. 1.1). In other words, engineering design represents a match point between theory and practice, or, as well, between desirable goals and technical feasibility. The scheme has been noticeably popularized by the book "Engineering design: a systematic approach" authored by Pahl and Beitz [1.1], which is, if not really a holy text, surely a pivotal reference for the scholars of the field.

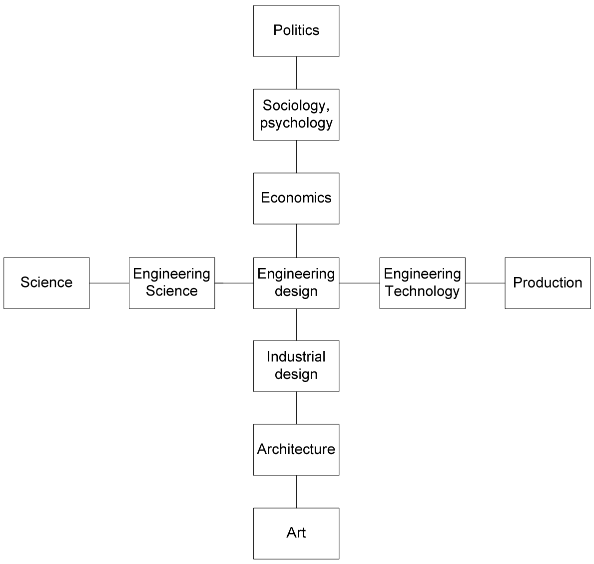

Fig. 1.1: Engineering design as a match point between different scientific disciplines; readapted from [1.1]

However, the original source of the cross-like representation is a less known volume dating 1966 [1.2], whose title is “Design Engineering: Inventiveness, Analysis, and Decision Making". The heading of the book could almost fit the title of the thesis. The contents of the work are indeed full of concepts and findings about “design” (and especially “engineering design” as well), “analysis” methods and tools to support “decision making”. Notions about “inventiveness” in design are surely not missing, thanks to the background of the candidate in Intellectual Property and Theory of Inventive Problem Solving (TRIZ) [1.3]. But the difference in the title of the thesis would exactly regard the word “Inventiveness”, which could be better replaced with the term “Innovation”.

Whereas inventive solutions are believed as brilliant and cutting edge ideas, they still miss the capability to impact the market or the society in order to become innovations. Unequivocally, several scholars deem innovative products as inventive or new artifacts capable to capture customers’ attention and hence to be sold [1.4-1.5]. In this sense, conspicuous efforts are made by enterprises in looking for the right way out on the market for new and outstanding technologies [1.6-1.8]. It is besides claimed that industrial evolution has entered a new era, where innovation capabilities represent the core assets to stay competitive (e.g. [1.9]). Hence, both originality and usability/attractiveness of products have to be continuously sought and pursued in order to allow the survival of organizations.

Contextually, one of the main focuses of engineering design community concerns creativity and the attempts to assess it quantitatively. Although the whole set of dimensions of design creativity is not completely shared by scholars, all of them include “novelty” and “usefulness” [1.10-1.12]. Once again, the determinants of well performing designs do not comprise just the newness of artifacts, but encompass also the capability to be valued by product users.

Further on, by observing the basic trends in the field, Faste [1.13] states how 21st century engineers have to acknowledge and embrace the human nature of their endeavor. If his intuition is correct, engineering designers have to pay higher efforts in achieving the capability of their products to be marketed (rather than the newness) and the usefulness within creativity factors. As well, in a different perspective, the vertical ax of the scheme reported in Fig. 1.1, has to be investigated with higher priority than the horizontal line.

In this sense, it is firstly required to investigate those industrial tasks and business areas resulting crucial for innovation to take place. A particular attention has to be dedicated to highlight the main deficiencies of industrial practices and proposals originating from academics, which hinder the display of successful innovation projects. The survey has to focus especially on those features that conflict with the expected effort towards a major consideration of the human factors, the customer sphere and the effective usefulness of the produced designs.

Innovation in industry concerns two main domains (the product and the process), which are commonly treated as separate areas, despite the claims for integrations [1.14]. Product innovation regards the redesign of the commercial offer which tends to include physical artifacts and matching services. The trend has brought to the birth of a new discipline, i.e. Product Service Systems [1.15-1.16], based on observed modifications in industry (at least in the Western countries) and concerns for sustainability. Anyway, creative engineering design initiatives go commonly under the name of New Product Development (NPD) tasks, regardless the ideation of services is considered. Subsection 1.1 insightfully reviews the activities included in NPD cycles with a particular aim to those stages majorly impacting innovation results.

With respect to process innovation, the last decades witness numerous experiences to restructure industrial practices and manufacturing activities, generally referring to Business Process Re-engineering (BPR). Subsection 1.2 is devoted to analyze this field.

Subsection 1.3 summarizes the emerging weaknesses characterizing methods devoted to systematically re-engineer products and process. Eventually, Subsection 1.4 clarifies the focus of the work, the research areas for which the present thesis majorly provides contributions from a methodological viewpoint, the structure of the whole dissertation.

1.1 Product planning as a reference design phase for ideating innovative artifacts

As clarified above, the capability to innovate the commercial offer is becoming a key aspect for the survival of companies due to the high competitiveness of the market. Among the tasks to be accomplished by an organization, design undoubtedly represents an important ring in the value generation chain, which gives rise to successful products and services complying with customers' expectations [1.1]. Initial design stages and markedly Product Planning, result particularly crucial to determine whether the outcomes of NPD tasks will thrive in the marketplace. In this perspective, a plenty of proposals have been advanced to advantageously carry out the design of new products. However, despite some decades of research focused on NPD processes, the attempts have not obtained the expected results [1.17], especially from the viewpoint of introducing formal practices and methodologies in industrial contexts. This situation is even more remarked for Product Planning. Despite its strategic role, surveys about the most diffused and acknowledged design methods (e.g. [1.18]) highlight that a major attention is actually paid towards the final steps of NPD, aimed at improving technical solutions and detail aspects. The following

Subsections will pinpoint the definitions of Product Planning, its role within engineering design, review the existing methods and approaches and eventually illustrate the main inputs that have led the candidate to propose new tools in the field.

1.1.1 Insights about Product Planning

1.1.2.1 The strategic role of Front End activities within new product design

Actually, several schemes of NPD exist (e.g. [1.1; 1.19-1.20); however, even though quite different terminologies are used, all of them can be represented through the overall model shown in Figure 1.2.

Fig. 1.2: Simplified model of the product development process.

The first two phases of the product development process, i.e. Product Planning and Conceptual Design, generally constitute the so-called Front End.

Conceptual Design is acknowledged as a fundamental step towards the definition of original, novel and sustainable technical solutions (e.g. [1.21]). Product Planning consists in the identification of customer needs, the analysis of current lacks in the market and the definition of new product characteristics capable to fulfill customer expectations [1.1]. Therefore, the outcome of this phase constitutes the product idea on which the company will concentrate design efforts and resources (e.g. [1.22]).

The Back End ranges from Embodiment Design to those activities oriented to the introduction of new artifacts in the marketplace [1.20; 1.23-1.37].

It is acknowledged that some tasks that result more crucial in determining the successful achievement of innovation initiatives. In this sense, the literature witnesses a noticeable impact of Front End activities [1.20; 1.28; 1.31; 1.37-1.47]. Indeed, several scholars highlight that a great percentage of product failures is ascribable to inefficient planning activities [1.36; 1.39-1.40; 1.48-1.52]. Moreover, Ulrich and Eppinger [1.34] estimate that up to 80% of the forthcoming cost of a product is committed by the decisions undertaken in the initial phases, as well as, according to Achiche et al. [1.36], expenditures for revising these decisions drastically increase as the product development process progresses. Furthermore, managers and researchers [1.40; 1.53-1.56] claim that improvements in the management of the Front End phases are capable to produce benefits far exceeding those resulting from enhancements concerning later stages.

The careful accomplishment of the activities at the beginning of design cycles strongly reduces problems in the subsequent product development tasks [1.17; 1.28], drives revenues and increases firms profitability [1.31; 1.33; 1.51; 1.57-1.60]. In brief, well-managed initial design phases are the prerequisite for creating successful new products [1.20; 1.31; 1.41; 1.61-1.65]. As claimed by Pahl and Beitz [1.1], formal processes through which to perform Front End phases help the fruitful execution of the whole product development cycle. Notwithstanding the critical role they play, initial design phases still result insufficiently supported [1.17; 1.32; 1.35; 1.38; 1.41; 1.66-1.67].

1.1.2.2 Definitions of Product Planning

In the literature, the term “Product Planning” has been adopted to define different design activities. Some scholars (e.g. [1.68-1.69]) affirm that the main activity of Product Planning is the translation of identified client wishes into product technical requirements, using the Quality Function Deployment (QFD) [1.70]. Other authors claim that the main objectives of the Product Planning phase are the assessment and selection of alternative product concepts [1.71]. Kahn [1.51] defines the Product Planning as the process of envisioning, conceptualizing, developing, producing, testing, commercializing, sustaining and disposing of organizational offerings, i.e. he considers the whole product life cycle. Besides these definitions, it is widely accepted [1.1; 1.22; 1.28; 1.34; 1.50; 1.72-1.73] that the main objective of Product Planning is the identification of new product features, capable to fulfill customer expectations, in order to exploit new market opportunities. With this meaning, one of the main outputs of Product Planning is the list of product requirements, which has to be taken into account in the subsequent design phases for defining, selecting and developing the most valuable technical solutions. The thesis adheres to the last definition and employs such a concept of Product Planning in the residual of the work. By referring to customer expectations, Product Planning has to take into consideration the benefits generated by both physical goods and intangible services (e.g. [1.17; 1.33]). For the sake of brevity, the candidate will diffusedly use the term “product” for indicating any commercial offer that includes characteristics pertaining to both products and services (thus physical artifacts, pure services, mixes of tangible products and related services).

1.1.2.3 Product Planning activities

The main activities forming the Product Planning process are currently the generation of ideas about the new product to be developed and the subsequent selection of alternatives [1.33; 1.74-1.78]. Said activities and additional operations commonly taking part to the Product Planning phase will be discussed in detail in the following subsections.

The idea generation, sometimes called Opportunity Identification stage [1.28; 1.36], allows identifying attributes, features or general ideas of the product to be developed [1.33; 1.37]. For this reason, it can be considered the basic task of Product Planning and it has been widely investigated in the product development literature [1.33; 1.75]. Creativity stimulation plays a key role for the scopes of idea generation [1.79] and several techniques and tools have been developed to support this activity (e.g. [1.80-1.82]). Although a well-managed idea generation can be considered as a primary source of commercial success [1.65; 1.77; 1.83-1.84], many companies do not allocate sufficient resources to perform this stage accurately [1.33; 1.85-1.86]. Such a discrepancy can be put into relationship with the perception of idea generation as a random process, where ideas may be detected only by intuition, observations, discussions or accidents [1.87]. Furthermore, as stated in [1.33], managers are generally not sure of the best way of generating new product ideas and follow a “try it and see” approach. As a result, even recent proposals about structuring the Front End of the product development process disregard the ideation process [1.37; 1.65].

The idea generation phase usually gives rise to several product ideas. Hence, this divergent activity must be followed by a convergent idea selection task [1.88]. The idea selection, sometimes called Opportunity Analysis stage (e.g. [1.28-1.29; 1,36]), constitutes the decision-making phase of the Product Planning that allows choosing the alternatives to be further developed, on which the company relies. Several studies focus on the role of this step within the product development process [1.74, 1.76-1.78].

Nevertheless, many companies lack a coherent or formal process for selecting ideas [1.35; 1.67] and they are often unable to distinguish lucrative from poorly beneficial alternatives [1.88]. Moreover, the previous idea generation phase may generate so many ideas that the selection of the best ones becomes extremely time-consuming and requires vast human resources [1.35; 1.89-1.90]. Eventually, the early assessment of ideas is even tougher when projects aim at generating radical innovations [1.74; 1.77-1.78], due to greater uncertainties about potential market results.

Besides idea generation and selection tasks, the literature about Product Planning focuses on other activities, which are less directly connected with the product. They include monitoring the financial position of the company [1.19; 1.22; 1.72], allocating resources and planning timing [1.22; 1.34], analyzing existing and potential new technologies [1.19, 1.22; 1.34, 1.72], identifying legal regulations and patents [1.44; 1.91]. All these activities play a not negligible role in the commencing stages of product development, by supporting the management of available resources. As better illustrated in Section 1.1.2, all these tasks are out of the scope of the present work, because they mostly concern the management of innovation projects rather than measures for determining successful product profiles.

1.1.2.4 The accomplishment of Product Planning in the industrial practice

As mentioned above, the diffusion of formal approaches to accomplish Product Planning is very limited. In many cases, markedly in SMEs, Product Planning is entrusted to intuition and experience of few decision makers [1.1; 1.50, 1.92-1.93]. This fact is largely confirmed by a recent experience of the candidate's research group within a project aimed at investigating the practices and the competitive difficulties of enterprises operating in Valdelsa area, Tuscany Region, Italy. The candidate interviewed 20 firms, which manufacture products they design and belong to 5 different industrial domains (caravans, glass and crystal, furniture, tools for wood processing, machines for the building sector). It emerged that the employment of structured methodologies supporting the Fuzzy Front End is extremely limited. Among the existing tools, just Brainstorming (see Section 1.1.2.5 for major details) seems to be known and partially adopted within the surveyed firms. Besides, the name of the method is commonly employed to describe regular meetings among decision-makers rather than a structured approach for generating new product ideas.

Still according to literature and empirical observations, larger companies carry out Product Planning tasks by benefitting from conjoint activities that often involve multidisciplinary teams constituted by marketing and technical experts. In such a kind of enterprises, marketing professionals usually perform a preliminary benchmarking analysis of existing products and competitors. They examine the needs expressed by end users, taking the Voice of the Customers (VoC) into the company and consequently support the product development team with their market knowledge. Designers, managers or R&D teams analyze the marketing outputs and investigate the most promising and technically feasible product features, in order to fulfill customer requirements. The multidisciplinary integration allows taking customer needs and technological capabilities into sufficient consideration, even in the early stages of the innovation process [1.94]. This strategy aims at reducing to the greatest extent both uncertainties about market results and problems related to the technical feasibility of products [1.77]. However, it is well known that the interaction between different units, like marketing and R&D, is often problematic in the Front End stages, mainly because of different mind-sets and perspectives [1.95-1.96]. For this reason, organizations often decide to entirely entrust the management of this phase to single units of the firm, whereas the marketing team is attributed of the main responsibilities concerning the business opportunities to pursue and the core competing factors of new products [1.97].

1.1.2.5 Critical issues

In order to understand the main critical issues of Product Planning, it is useful to consider the Front End of the product development process as a whole. Indeed, as clarified above, several scholars and practitioners face Product Planning and Conceptual Design together, because these phases have much in common. The initial part of the design process is often referred as “Fuzzy Front End” (FFE); the term has been first popularized by Smith and Reinertsen [1.57]. The adjective “fuzzy” has been attributed to Front End phases, because they typically involve random process and “ad hoc” decisions based on intuition, observations, discussions or accidents [1.17; 1.27; 1.87]. Many professionals and researchers do not judge FFE as a structured process because of its intrinsic fuzziness, ambiguity and uncertainty [1.20; 1.33; 1.39; 1.41, 1.66]. Such a circumstance is reflected in the behavior of many companies, which have not implemented a structured approach to follow, nor they entrust formal methodologies [1.17; 1.20, 1.28; 1.31; 1.36; 1.39; 1.98-1.99]. On the contrary, a great number of organizations focus their attention on Back End activities, for which acknowledged methods are more diffused, by primarily aiming at reducing manufacturing errors. According to [1.28], this strategy is however hazardous, because the disregard of the FFE can lead to product failures or anyway to great expenditures for revising decisions, which dramatically increase as the design process progresses (Fig. 1.3).

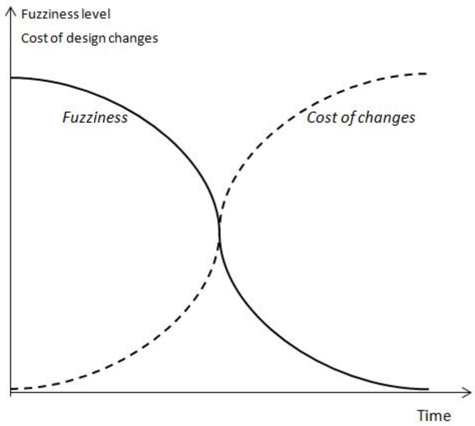

Fig. 1.3 Cost of changes VS fuzziness in the product planning process (adapted from [1.41; 1.100])

In order to reduce the "fuzziness" of early product development stages and contextually support design decisions in these phases, several scholars [1.22; 1.28; 1.37; 1.66] developed formal and comprehensive procedures for supporting the Front End activities in a more systematic way. Proposals to better manage the FFE include organizing teams swiveling on FFE activities [1.41], managing in different ways the fuzziness related to customers, technology and competitors [1.40], focusing on the available resources of the company [1.36]. Besides, software tools are claimed to speed up the commencing part of NPD process, reduce costs, increase collaboration, improve decision quality and knowledge management, reduce risks and enhance overall creativity [1.46].

Notwithstanding a not negligible amount of contributions attempting to overcome uncertainties and ambiguities inherent to the FFE, the goal of effectively managing and performing the ideation of new products and their implementation into technical solutions is actually far from being reached. On the one hand, computer applications require additional and more specific empirical researches, because the benefits they should provide have not yet been rigorously studied [1.46; 1.82]. On the other hand, many suggested procedures explain the required activities to be performed, but lack to individuate appropriate tools for accomplishing FFE tasks, especially those pertaining to Product Planning. Promising strategies to manage the FFE have not yet received up to now ample evidence or currently require too much information to work correctly. In each case, the cited proposals have overall a poor orientation towards the products to be developed and the valuable characteristic to be fulfilled. In other words, many success factors of the product development process do not pertain to what is directly designed, manufactured and marketed.

In this sense, some sources [1.17; 1.33; 1.35; 1.101] suggest that FFE can become much less **"**fuzzy" if customers are involved in the initial stages of NPD. This thought is however not shared by other authors (e.g. [1.102]), who argue that customers fundamentally focus on already fulfilled needs and consequently the opportunities potentially emerging from the exploration of new market domains get lost.

1.1.2.6 Need of a review about Product Planning methods

Subsection 1.1.2.5 has clarified how Product Planning represents a critical phase within NPD processes and a potential vector of business success. It has been also pinpointed how a great amount of its effectiveness depends on leaders' intuition or on the results produced by working teams often missing some of the needed competencies. The candidate shares the belief that more systematic approaches can result beneficial also in this product development stage, which is, in the practice, pronouncedly entrusted to individual skills, such as creativity and business instinct. As well, it is deemed useful to work more on those activities that directly involve the product and its distinguishing features, while the studies about the management of the early stages of NPD cycles [1.83; 1.103-1.104] and the strategic positioning of development projects [1.84, 1.105] have already brought to several evidences, e.g. the relevance of trust in cross-functional teams. State-of-the-art analyses about several aspects of NPD tasks have already been carried out (e.g. [1.65; 1.97; 1.106]), as well as proposals of integrating Product Planning with other design phases have been advanced [1.107]. However, whereas reviews are quite dated or do not examine in detail the contributions intended to develop and choose product ideas, best practices including means for carrying out Product Planning are not sufficiently acknowledged yet. With these premises, the following Section illustrates the criteria adopted to browse the literature and to select the relevant sources for setting up a state-of-the-art analysis of methods employable in the industrial environment for generating and developing original product ideas. Insights from this review will be used as drivers for proposing new tools, which will be illustrated in the next Chapters.

1.1.2 Review of product planning methods

1.1.2.1 Research criteria

As remarked in Section 1.1.1, Product Planning presents two basic activities, i.e. idea generation and selection, which are more closely connected with intrinsic characteristics of innovative products. Thus, the review does not comprehend studies which emphasize the importance of the corporate image [1.108], brands [1.109], advertising [1.110], retailing [1.111], pricing [1.112]. However, the review includes methodologies that support planning activities besides idea generation and selection, but just their contribution to the recalled basic tasks will be discussed.

The analysis comprises formal methods, i.e. more or less systematic procedures, and software tools to support Product Planning. The scrutinized methods can be distinguished into those with an initial focus on general product ideas and approaches that consider customer requirements as a starting point for innovation initiatives. Product features can be subsequently articulated in order to create an innovative product profile, i.e. a bundle of attributes associated with their matching offering levels to be transformed into an original product architecture. Conversely, turning general product ideas into a list of product characteristic is extremely helpful into the subsequent design phases. For the sake of completeness, the survey has been limited to those methods that support the user in defining the list of competing factors (or in identifying the basic information to intuitively obtain it), which consequently allow to carry out product development cycles in the industrial practice. Such features include both current product characteristics and new attributes, commonly introduced to satisfy emerging or unspoken needs. In the remainder of the thesis, the term “latent needs” will be used to indicate the complex network of unprecedented customer requirements that are discovered, stimulated or aroused.

Furthermore, just contributions demonstrating the applicability of the proposed methods in industry or documenting real case studies have been considered for the scope of the research.

The literature search has been essentially oriented to literature sources within engineering design and innovation management. More in details, the survey has included different research sectors dealing with Product Planning and considered different jargons according to scholars’ field of expertise. Besides “Product Planning”, the main drivers for performing the research follow, indicating reference works that extensively use the matching terms:

- Fuzzy Front End [1.20; 1.37];
- New Product Development [1.1; 1.34];
- New Value Proposition [1.113];
- customer needs and satisfaction analysis [1.25; 1.115];
- company general planning [1.51; 1.115];
- product innovation [1.28; 1.116];
- analysis of product success factors [1.65; 1.83];
- idea generation [1.33; 1.35].

1.1.2.2 General approaches to perform Product Planning

It is well-acknowledged that the key to achieve organizational goals is to be more effective and efficient than competitors in identifying and satisfying the needs of target markets [1.117-1.118], developing and delivering products that are valued by customers (e.g. [1.63; 1.113]). According to this objective, two main categories of approaches can be identified in literature: responsive and proactive methodologies [1.117; 1.63].

The former consider the industrial standard as a reference for identifying lacks in the offered product features and in the delivered performances. Responsive methods swivel on marketing surveys whose results are used as input information to define a new product idea. Hence, the task of pointing out desired improvements is almost entirely entrusted to the end user, who represents the real decision-maker. For this reason, the term “market (or demand) pull” is often used to define this kind of strategies [1.119-1.122], while the innovation strategy implemented through these approaches is mainly based on the fulfillment of expressed needs. Therefore, the team in charge of the Product Planning task has to collect, analyze, interpret the customers expressed needs and translate them into product requirements. The first three activities are typically managed by the marketing professionals, whereas the fourth one is often delegated to designers.

Proactive methods attempt to capture unspoken wants of customers or even induce new needs for end users. They aim at developing product ideas radically different from the industrial standard. Therefore, these methods do not involve the end user in the investigation of the aspects that could represent potential innovation opportunities. Benchmarking analyses, usually performed by marketing experts, are used to analyze the market context, while the decisions about the definition and the selection of the most promising product ideas are totally in charge of design teams. This category of methods includes the so-called “technology push” strategies [1.120-1.123], in which emerging technologies can be exploited as driving forces for disruptive innovations [1.124]. However, the use of a new technology is not generally sufficient to ensure the market success [1.17; 1.52; 1.125]. Therefore, a balanced R&D-marketing coordination is strongly recommended to carry out proactive approaches [1.125-1.126].

Besides the recalled typologies of methods, the survey proposed in this thesis has revealed the existence of contributions that merge, as a matter of fact, peculiarities of both responsive and proactive approaches. They essentially try to discover and fulfill customers’ latent needs by involving the end users of the product or service in the idea generation process. Indeed, the users are asked to provide feedback about the new product ideas that are generated by the design team and/or collaborate in proposing new ones. A further category of contributions is therefore introduced because of this evidence, namely “Hybrid”, through which to classify all the methods that present both responsive and proactive characteristics.

The surveyed Product Planning methods have been classified into the three broad categories introduced above, i.e. responsive, proactive and hybrid. The following Subsections 1.1.2.3-1.1.2.5 are articulated according to such distinction. Each of them includes the description of the collected contributions and highlights their strengths and weaknesses.

1.1.2.3 Responsive Methods

Responsive methods focus on the analysis of the VoC, which is generally taken through questionnaire surveys. Many scholars [1.25; 1.28; 1.34; 1.42; 1.44; 1.115; 1.127-1.130] claim that bringing the VoC into an organization is a key process of the Front End of product development. In this context, the main efforts of the scientific community are devoted to the development of data analysis tools aimed at supporting the identification of the main customer preferences. Several methods based on responsive Product Planning strategies can be identified [1.17; 1.34; 1.118; 1.127-1.128; 1.131-1.132], but, according to the criteria described in 1.1.2.1, a subgroup of contributions has been chosen as a sample to be analyzed in detail for the scopes of the present review. More explicitly, the examined contributions include non-trivial VoC surveys providing indications about the product requirements to be fulfilled with the highest priority. The surveyed proposals include the original Kano model and its developments, as well as some representative decision support tools, which match customer opinions and other factors to select the most beneficial product characteristics.

Kano model [1.133] is a well known tool and theory which constitutes the core of several methodologies extensively applied in different industrial contexts (e.g. [1.134-1.136]) and its developments still represent a hot topic, especially within Total Quality Management context [1.137]. It allows analyzing the relationship between the offering level of product attributes and the consequent customer satisfaction through the employment of ad-hoc questionnaires. The model provides an effective approach to help understanding the potentiality of each product attribute [1.134-1.135] by emphasizing the asymmetric relationship between performances and perceived satisfaction and highlighting the different effects of poorly fulfilled customer requirements. In addition, Kano [1.138] has explained the possible dynamics of the customer preferences, as widely discussed in [1.139]. By providing additional information about the transformations occurring to the perception of customer requirements, guidelines have been proposed to support the planning of new products. These emerging indications have been experimented by other scholars [1.136; 1.140-1.141]. However the dynamics of the customer preferences can change according to the type of product [1.136], the market context (e.g. Japan, USA, China) and the customer experiences [1.138], thus limiting the applicability of Kano model. Furthermore, whereas the theory and its developments contribute to stress which product attributes or features to invest on, a lack of Kano-based methodologies stands in the poor capability to help the individuation of new valuable product attributes.

Liberatore and Stylianou [1.142] as well as [1.143], have suggested a set of statistical tools to combine the inputs coming from customer surveys, market and financial analysis, expertise of internal personnel, in order to generate a list of the most beneficial product requirements. These instruments have been implemented in computer-aided systems and tested through an industrial case study in companies involved in flooring industry [1.142] and agriculture [1.143]. Even if a single test cannot constitute a proof of reliability and general applicability, the tool developed by Matsatsinis and Siskos [1.143] seems to be ready-to-use in different industrial fields, because it uses a generic formulation that makes the approach adoptable for variegated products. Furthermore, it integrates a forecasting tool that supports the analysis of customer preferences dynamics. Such a characteristic results useful for responsive methods because customer surveys often involve time-consuming activities, thus customers’ preferences can change in the meanwhile. The two methods need both marketing and technical competencies in order to respectively support the analysis of the VoC and the definition of product requirements. Their main strength concerns the competitors' analysis that provides the design team a clear market vision. On the other hand, the main weaknesses are related to the statistical analysis that requires significant data samples and subjective experts' opinions, viable to jeopardize the reliability of the results.

Chan and Ip [1.144] have proposed a method that follows a different procedure, if compared to previous contributions. The design team has to assess, on the basis of experience, the most beneficial product attributes and features for the end user. The emerged characteristics are submitted to several samples of potential end users to analyze the purchasing behavior through questionnaires. Then, the obtained data are matched and the best set of product features is identified. This method provides also a forecasting analysis to take into account the dynamic behavior of the customer preferences. The scholars applied the method in an industrial context (power tool industry) obtaining encouraging results; however, also in this case, a single test is not sufficient to fully assess its reliability. Furthermore, the considered approach shares some weaknesses with those previously cited, because it needs to collect and analyze significant data samples and requires subjective inputs. However, subjectivity issues are better managed, since the comparison among surveys can highlight the presence of incongruities.

Liao et al. [1.145] have proposed an original method of data analysis that investigates the relationships among customer demands and product characteristics. The method analyses the outcomes of customer surveys including target information (e.g. gender, age, purchase habits) and customer preferences, expressed in terms of most interesting product features. The data are combined with the aim of identifying specific needs of groups of customers and developing appropriate offers to certain market segments. Therefore, this approach provides a complete picture of the customer demand, which can be used to support all decisions in the Product Planning phase. The scholars applied the method in cosmetics industry and claimed that their approach can be generalized and employed in different fields; however, no application is currently documented in other industrial contexts. In addition, also this method requires significant data samples in order to obtain reliable results.

Generally speaking, the improvements in the management and exploitation of customer surveys supports the thought of some researchers [1.146-1.148], who claim that responsive approaches can reduce the level of uncertainty related to the market response towards new products ideas. The interest in monitoring the dynamics of consumers' tastes helps in overcoming an acknowledged lack of responsive methods, which are supposed to be characterized by their inability to capture the shifts in customer needs and market conditions [1.117; 1.147]. Indeed, it has to be noted that the execution of massive customer surveys requires a considerable amount of time for interviewing consumers and analyzing data (see e.g. the resources committed by Liao et al., [1.145]). Besides representing a problem in the perspective of shortening the time-to-market, long times are supposed to alter customers' tastes and then to drastically reduce the validity of surveys, especially in the volatile markets of the 21st century [1.149]. On the other hand, the illustrated methods reflect the weaknesses that are generally attributed to responsive approaches. By entrusting customers' feedback, highly responsive firms may be unable to differentiate themselves from their competitors, due to the low interest in new knowledge and alternative development directions [1.148]. This can be considered a consequence of the fact that many organizations are not capable to gather important customer information, because they lack awareness of which kind of data result the most valuable, the required skills, formal processes to perform the surveys [1.17]. Eventually, responsive methods cannot provide useful aids to design new features and market contexts, whose exploration is hindered by relying on customers' requests [1.102; 1.150-1.152]. Indeed several authors [1.17; 1.52; 1.153] have argued that customers are not able to conceive the benefits of radically innovative products. Therefore, anticipating what customers will value cannot be achieved uniquely by gaining their preferences, experiences and goals [1.17; 1.154].

1.1.2.4 Proactive Methods

Proactive methods support the development of breakthrough product ideas without involving the end user in the Product Planning phase. A growing body of research [1.27; 1.33; 1.39, 1.58; 1.60] suggests the use of proactive strategies in the NPD to boost the chances of developing successful innovations. In this field, the scientific community has focused its main efforts on the development of tools supporting the analysis of the reference market and the discovery of the end users' latent needs. Proactive approaches, as those analyzed in detail in the present Subsection, leverage individuals' creativity to generate superior value for customers.

Lateral thinking [1.81; 1.155] is a well known technique with a considerable diffusion in industrial contexts [1.156], that can support the generation of new product ideas. This approach, unlike logical "vertical" thinking, pushes individuals to think from different perspectives, overcoming their psychological inertia and generating as many new ideas as possible. Several methods and tools can be used to support this task, e.g. Mind Maps (e.g. [1.82; 1.157]), Delphi method [1.158] and Six Thinking Hats [1.159]. The last one can support idea selection too and it can even be used to make forecasting analysis (e.g. to support the analysis of customer preferences dynamics). The main weaknesses of lateral thinking stand in its low systematic level and inefficiency

[1.170] Indeed, the approach is considerably based on subjective inputs and random processes.

The Blue Ocean Strategy (BOS) fine-tuned by Kim and Mauborgne [1.113] is a mind-set aimed at supporting NPD initiatives, which is observing a growing consensus in industry [1.161]. It provides thinking tools intended to discover possible radical modifications of current industrial standards. Starting from a benchmarking analysis, the designer identifies a new product profile, i.e. an unprecedented set of product features, by the application of guidelines empirically obtained through the careful analysis of past market successes. Unfortunately, although these tools seem to have a general validity, their reliability has still to be demonstrated. Moreover, the BOS toolkit offers only mere qualitative indications that are not sufficiently systematic to support the designer during the whole Product Planning process [1.162].

Differently from previous proposals, Lee et al. [1.163] have developed a procedure that supports all the basic activities of Product Planning. The method involves a design team striving to identify the potential user needs and product requirements through a scenario-based analysis. This practice aims at reflecting upon most likely product use scenarios and alternative future developments. Scenario-based techniques are already diffused in industrial environments as a means for identifying new products ideas, giving rise to satisfying results [1.17; 1.51; 1.128]. The following selection of the most profitable set of product features is performed according to a criterion based on a benefit-cost analysis. The proposal has been tested through an industrial case study (i.e. the development of a tangible user interface) obtaining good results. A remarkable limitation is constituted by the need of a large design team since the members have to confront each other during idea generation and selection to obtain reliable results.

Ultimately, although the individuation of the proper user factors to be considered in order to provide greater value remains an open issue [1.164], efforts have been made to discern good from bad business opportunities. Anyway, the surveyed proposals diffusedly reflect the outcomes resulting from the analysis of proactive methods performed by Ulwick [1.102], which shows how proactive approaches might guide the designer towards product ideas resulting too distant from customer preferences. As a matter of fact, many firms lack formal processes for anticipating unspoken customer needs [1.17], making the employment of proactive strategies extremely hazardous. In addition, some scholars [1.31; 1.35] claim that this kind of strategies, as opposed to responsive methodologies, are quite complex and produce radical innovations whose market results are markedly uncertain. Eventually, Levinthal and March [1.165] claim that the overall expenditures occurring during proactive Product Planning are usually higher than tasks carried out through responsive practices.

1.1.2.5 Hybrid Methods

As previously claimed, hybrid methods merge characteristics of responsive and proactive approaches. These methods can involve the customer:

- in an active way, with the aim of collaborating in the generation of new product ideas;
- in a passive way, with the aim of obtaining preliminary judgments about new ideas.

The active involvement of the users represents a distinguishing factor of the well-known Brainstorming method, originally developed by Osborne [1.80]. This approach is extensively used in the industrial practice [1.156; 1.166], because it can be easily and intuitively implemented, even if in most cases it is implemented in a naïve way, not fully aligned to the original Osborne's recommendations. A group constituted by end users, guided by a moderator, discusses about new product ideas. At the end of the procedure, the design team analyses the results and compares the collected ideas and their feasibility. Several practices and techniques to support brainstorming sessions have been experimented in several decades, e.g. Synectics [1.167], Brainwriting [1.168], Mind Maps [1.157], Bodystorming [1.169], and so on. However, companies often develop their own customized technique, according to their needs. Brainstorming can support, in principle, both the main Product Planning activities. Nevertheless, some authors [1.88; 1.170] highlight that brainstorming participants seem to be unable to distinguish valuable from poor ideas.

Osborne stresses the importance of focusing on the quantity rather than on the quality of the ideas, by claiming that the abundance of hints results in greater chances of achieving successful outcomes. However, too many alternatives create considerable problems in the selection phase and the scarce quality of the outputs can lead to not lucrative results. In addition, whereas Brainstorming advocates claim that such method is more effective than entrusting idea generation to a plurality of individuals working separately, other studies [1.75; 1.88; 1.171-1.172] assess that groups employing Brainstorming produce a smaller quantity of ideas (besides less feasible).

In the last years, several software tools to support brainstorming have been developed, as surveyed by Hüsig and Kohn [1.82], giving rise to the so-called "electronic brainstorming" [1.173]. Some researchers [1.174-1.176] claim that these tools can improve both the efficiency of idea generation (e.g. number of ideas per participant) and the effectiveness of the ideas (e.g. ideas viable to be successfully implemented). According to [1.176-1.177], the most advantageous strategy is allowing thinking groups to work together supported by electronic brainstorming, rather than collecting the ideas generated by single human-computer interactions.

The Lead user method, finalized by Von Hippel [1.178-1.179], does not consider all the potential customers, but only pioneer users (lead users) of a product. Pioneers have spent more time in using the product with respect to the rest of the customers, hence they probably have experienced needs still latent for many potential clients [1.115]. Thus, the company has to identify the lead users, e.g. through Internet searches, and involve them in the Product Planning phase. Such users are asked about new potential product features or original product ideas. Von Hippel's method supports only the idea generation phase, is quite intuitive, but the results based on users' ideas might result unfeasible for the company.

A more systematic contribution is proposed by Büyüközkan and Feyzioğlu [1.180], which exploits an Internet database to collect new product ideas within a specific industrial context. Ideas are then generated not only by company designers or product managers, but also by customers and employees as well. It can be observed that many organizations disregard the opportunity of consulting with employees [1.35; 1.181-1.182], although they are a free and quick source of ideas for the company [1.183]. The developed database includes also an internal system where product managers can introduce proposals based on competitors' products and benchmarking reports. The selection of the most promising idea is supported by a computer-aided tool, which uses a historical database collecting successful and unsuccessful product cases and a set of company's constraints. The application of this approach to an industrial case study in a toy-manufacturing firm has demonstrated its capability to speed-up the Product Planning process. Moreover, the researchers claim that each type of firm can adopt this tool. Nevertheless, it is worth noting that the proposed method can be employed only if a great number of new product ideas are stimulated, being it based on neural networks. Moreover, a great limitation of the approach lies in the inconsistent results generated without the availability of an updated historical database, as claimed by the same scholars.

Kansei Engineering [1.184] has been developed in order to obtain customers' inclinations about product alternative ideas, which are previously collected by designers who analyze existing artifacts and/or conceive new ones. The method allows studying the emotional reactions of the customers up against descriptions, images, prototypes of new or existing products, their components and features. The focal belief stands in the assumption that products need to evoke the right emotions within the user, to distinguish themselves from those of competitors. Customers are generally asked to assess the proposed product ideas through questionnaires, which permit therefore to reveal the most promising alternatives. Hence, the method foresees a passive, although custom, involvement of the end users. The usability of the approach is enforced by a systematic 4-step procedure [1.185] that exploits Kansei Engineering capabilities. One of the advantages of Kansei consists in its general applicability, since it can be used for any product, service or component, as witnessed by a plurality of even recent employments in variegated industrial fields (e.g. [1.186-1.187]). Expert systems and computer application implementing the principles of Kansei Engineering are likewise diffused (e.g. [1.188-1.189]). On the contrary, one of the main weaknesses is related to the development of the questionnaire, since it is very tricky to find the right expressions by which to render the customer emotional reactions. Furthermore, cultural factors can play a misleading role in turning emotions to be aroused into product requirements to be fulfilled [1.190], as well as different peoples' mind-set and typologies of industries require adaptations of Kansei Engineering outside Asian countries [1.191].

Chen and Yan [1.192], as well as Kimita et al. [1.193], illustrate methods that support the designer in the process of generation and selection of product and service ideas, benefitting of customer surveys. As in Kansei, the end users are passively involved in the planning phase and provide feedback about ideas developed by the designers, who attempt to hybridize existing products features and identify new and existing services attributes through a brainstorming session. In addition, the method developed by Chen and Yan [1.192] can forecast customer preferences by performing a trend analysis of historical data that have been collected in the course of time by means of user surveys. Both the proposed approaches can totally support the Product Planning phase. Anyway, Chen and Yan show only a theoretical case study on cellular phone design to illustrate its applicability; therefore, the usability of the method has to be fully demonstrated. On the other hand, the method proposed by Kimita et al. [1.193] had already been successfully tested through a computer-aided tool [1.194], analyzing domestic in-flight services. Although they obtained encouraging results, the scholars affirm that in some cases the outcomes could not be considered reliable, due to the possible disregard of relevant services features. Thus, the idea generation phase should be supported by more systematic methods in order to obtain more rigorous results.

The proliferation of interconnectivity and interactivity through Internet-based technologies has fostered the introduction of new methods that might support NPD [1.195-1.196] and especially the idea generation phase [1.35; 1.179]. A common characteristic of these new methods is the use of distributed knowledge through the interconnection of ideas from a vast number of participants [1.35; 1.89]. Among these proposals, Füller and Matzler [1.197] have demonstrated the key role of virtual interaction tools that allow companies to gain valuable input from customers about new product ideas. The scholars illustrate the exploitation of Internet capabilities to support Product Planning in an industrial application. The users are asked to assess and modify, according to their needs and creativity, new product general ideas, or product features developed by designers. This process is iterative and the cycle terminates with a feasible product idea that meets customer needs. The novelty of this method, compared to conventional market surveys analyses, is that customers are not only asked about their opinions, wants and needs. Indeed, they are invited to contribute to the real development of the product, adding value to all stages of the innovation process, as claimed by Füller and Matzler [1.197]. However, the development of the Internet platform and the interaction with customers involve a great amount of time and resources and, likely, just big enterprises own the capabilities to use this tool. Furthermore, this method implicates issues about the secrecy of NPD projects (due to the easy access to many Internet sources), so that competitors can take advantages from the obtained information.

One of the new frontiers in hybrid methods concerns the identification of customer latent needs analyzing end users' psychological responses through the use of brain scanning and other technologies for measuring physical activities [1.198]. However, these noteworthy techniques cannot be considered still thoroughly reliable, due to their very early stage of development.

Ultimately, the presented analysis highlights that hybrid methods merge together not only the positive aspects of both proactive and responsive strategies but, sometimes, also their disadvantages.

1.2 The reengineering of industrial processes and its impact on innovation of firms

The present Section introduces the concept of "business process" and illustrate reference methodologies aimed at modifying industrial practices on the basis of BPR principles.

1.2.1 The reasons for achieving the redesign of business processes

As clarified above, all the products have to pursue continuous improvements in order to satisfy new customer requirements or novel market demands. This task implies an evolution of the production process at different levels. In some circumstances minor reorganizations in the design or production phases can be sufficient to fulfill the evolving product requirements; besides, these actions usually bring only to limited improvements mainly focused on preserving the competitiveness of the product in the marketplace.

In other market circumstances, companies have to develop more remarkable innovations. Boundary conditions, such relevant discontinuities in customer perceived value and preferences, lead to the implementation of radical technological changes [1.113]. Besides, limitations of available resources are a common trigger for impending transitions of mature technical systems [1.199] or even established service industries [1.200]. Disruptive innovations can be brought also by performing a careful analysis of the possible aspects of value that consumers might care about, such as way of using, further technical or emotional features, resources consumption, maintenance, environmental impact, customer care, end of product lifecycle.

However, novel product ideas often show relevant problems to access market due to a large amount of factors such as design or manufacturing costs [1.201], organizational issues [1.202], required technologies or materials [1.203], undesired effects [1.204], resources consumption [1.205]. All these kinds of limitations represent significant hurdles to exploit new business opportunities, notwithstanding the realized products or the delivered services are viable to occupy a promising market space.

In such circumstances, the demand for innovation affects the industrial environment and particularly the business processes, which requires continuous updates and monitoring. As widely discussed in [1.206], constituting an integral part of the present thesis, «the concept of "business process" was born in the early 1990s as a means to identify all the activities that a company performs in order to deliver products or services to their customers. The need of describing and formalizing the actions performed to turn resources into benefits for the customer was strongly perceived in those years since companies started worldwide to radically reorganize their activities in the attempt to regain the competitiveness lost during the previous decade. The "business process" concept has been defined by several authors in the literature with the aim of providing a reference for modeling and analysis tasks.

Davenport [1.207] stated that it is "a structured, measured set of activities designed to produce a specific output for a particular customer or market. It implies a strong emphasis on how work is done within an organization, in contrast to a product focus's emphasis on what. A process is thus a specific ordering of work activities across time and space, with a beginning and an end, and clearly defined inputs and outputs. Processes are the structure by which an organization does what is necessary to produce value for its customers". Thus, according to Davenport, a business process is identified through clear boundaries, inputs, outputs and activities ordered in time and space: the purpose of the process is the transformation of inputs into outcomes having value for the customer. Hammer and Champy [1.208] give a more general definition focused on the process outcomes according to the customer perspective: "a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer". Eventually Johansson et al. [1.209] emphasizes on the creation of links and interrelations among the activities and on the transformation that takes place within the process, highlighting the value chain concept: ”a set of linked activities that take an input and transform it to create an output. Ideally, the transformation that occurs in the process should add value to the input and create an output that is more useful and effective to the recipient either upstream or downstream”.

Plenty of definitions have been proposed, but in essence all have the same meaning: business processes are basically relationships between inputs and out-puts, where inputs are transformed into outputs throughout a series of activities, which add value to the inputs» [1.206, §1.1.1]. Organizations willing (or requiring) to restructure their business processes have to take into consideration both inputs and outputs. Therefore, on the one hand, companies are asked to enhance the quality of products and services, so as to fulfill the growing expectations of customers and stakeholders. On the other hand, they strive to minimize costs. In this sense, a paramount importance is attributed to all those initiatives aimed at strategically redesigning industrial processes in order to accomplish radically higher performances and that fall under the name of BPR [1.207-1.209]. The literature witnesses considerable advantages arisen by BPR initiatives and describes textbook success stories. Some reference example follows, so as to describe the variety of the contributions

1.2.2 Illustrative examples of BPR experiences

An integrated multidimensional process improvement methodology has been proposed in [1.210] to address the yield management, process control and cost management problems for a production process. The Total Quality Management (TQM) is used to manage the cost of the system according to the quality requirements and a discrete event simulation is used to perform process re-engineering and process improvement.

In [1.211] a method has been proposed which supports the practitioners in developing a new improved business process starting from the current design based on a heuristic approach. The method has been extrapolated from different successful best practice approaches to BPR problems available in the literature. They have been synthesized in a checklist to support process redesigning by taking into account different management approaches: Total Cycle Time compression, Lean Enterprise and Constraints Management.

In [1.212] an investigation has been performed of BPR methodologies employed in different companies making products on engineering to order basis, that typically find business opportunities by the ability to respond to customer requirements,. The results show that BPR methodologies cannot be applied to such kind of companies since they are not able to manage different business units as in the case of collaborating companies.

A methodology has been proposed in [1.213] to assist the user in identifying the most appropriate lean manufacturing tools and techniques to address the problems of a particular company through a quantitative compatibility assessment. The results confirm that lean manufacturing tools may have a major impact only on specific areas of the business but not for companies experiencing problems in areas such as under capacity, scheduling and innovation in products and processes, which are not directly influenced by lean manufacturing methods.

The approach based on Balanced Scorecard (BSC) [1.214] provides a systematic tool for BPR by combining financial and nonfinancial performance indicators in a coherent measurement system. Four metrics are defined according to a selected strategy, and the company's processes are aligned towards this strategy. The company is evaluated in four areas: the financial perspective; the customer satisfaction; the internal business process view based on the concept of the value chain; a final index comprising innovation and the learning perspective. As stated in [1.215] BSC suffers from limits based on invalid assumptions about the innovation economy: its rigidity, its conception of knowledge and innovation as a routine process and its focus on the internal processes of the company, neglecting the relationships with the environment, make the BSC an insufficient tool for understanding and dealing with the innovation economy.

A number of works approach the problem of dealing with concurrent issues in terms of costs management and product requirements; a recent example is [1.216], where the integration of Value Engineering and Target-costing techniques is proposed to support the product development process in an automotive company. Such a methodology was applied to a case study aimed at improving costs and performances of a vehicle engine-starter system, according to customer and company needs.

1.3 Critical issues of methods for redesigning products and processes

The present Section highlights the main critical issues of product- and process- oriented reengineering approaches in order to clarify which aspects should be primarily taken into account when proposing new tools to foster innovation in industry. Whereas the examination of product development techniques has been illustrated in the thesis, indications about limitations of process re-engineering methods are directly extracted by authoritative literature sources, which have faced the problem of understanding the reasons of failures in implementing BPR approaches.

1.3.1 Weaknesses of Product Planning strategies

Each category of methods and tools that support Product Planning shares several pros and cons, as reported in Table 1.1, which summarizes the evidences arisen from the review performed in Section 1.1.2. On the one hand, responsive methods support the development of products that fulfill customer expected needs, reducing the uncertainty related to the market response. Consequently, these approaches are not suitable to support NPD initiatives aimed at breaking up the competition, as they do not take into account the exploration of new market domains. On the other hand, proactive methods are potentially capable to support the development of breakthrough products, since the search of new product ideas is performed by leveraging the creativity of designers and manifold sources of information, which however do not include customers' opinions. Potential consumers are indeed supposed to direct innovation processes towards products and services slightly differing from the existing commercial offer, being not capable to conceive new needs to be satisfied. Nevertheless, proactive methods result much less reliable than responsive approaches since the risk of developing products too distant from customer expectations and/or unfeasible is high. Eventually, hybrid methods can support the development of innovative products with a low level of market uncertainty, because they involve the customer in the Product Planning phase, but they generally require a great amount of time to obtain reliable results.

Table 1.1 Pros and cons of responsive, proactive and hybrid methods for Product Planning

	Strengths	**Weaknesses**
Responsive Methods	• Low level of uncertainty related to the market response towards new products ideas.	• Hindered exploration of new market domains; • Inability to adapt quickly to shifts in customer needs and market conditions; • Great amount of time and resources required, in order to obtain reliable results.
Proactive Methods	• Supported development of breakthrough products with unique benefits.	• Product ideas resulting too distant from customer preferences; • High level of risk and uncertainty due to the absence of customer feedback.
Hybrid Methods	• Supported development of innovative products with a low level of uncertainty related to customer feedback.	• Great amount of time and resources required in order to obtain reliable results.

Besides the general characteristics of Product Planning methods, illustrated in the Table, some issues seem to emerge as particularly impacting deficiencies of existing proposals. At first, Product Planning strategies aimed at ideating radical innovations by a structured approach seem totally missing. A scope of the research can be thus constituted by the attempt of deepening the knowledge behind proactive methods, so to enforce their usability. A reference in this subgroup of proposals to support Product Planning can be considered the Blue Ocean Strategy, given the popularity it has gained in the last years. Despite the diffused recognition, its industrial applicability is still limited due to lack of formalisms and especially to poor capability in addressing innovative product development process [1.217, § 2.2.1]. A first methodological objective posed by the thesis is the enhancement of proactive approaches dealing with the innovation of business models. The main achievements should be represented by the enforced guidance of these strategies and the capability to lead towards innovations likely to obtain success, thus limiting the set of product ideas to be subsequently investigated.

Lacks in the capability to undertake decisions are observed, once again, especially within radical innovations emerging from the employment of proactive methods. Such limitations constitute the basis for the main efforts of the candidate with respect to idea selection activities.

1.3.2 Deficiencies of existing BPR approaches

As seen in Section 1.2.2, the core of BPR methodologies acts by suggesting practical measures to restructure industrial processes. Notwithstanding the ease of implementing BPR practices and their fame (especially in the 1990s), several works in literature demonstrate the failure to meet their expectations. Among the others, Holland and Kumar [1.218] shows that 60–80% of BPR initiatives have been unsuccessful. A more recent investigation [1.219] does not contradict the large diffusion of unsuccessful experiences. As a result, several studies aim at providing greater understanding about the success factors and major effects of BPR initiatives [1.220-1.221], thus advancing guidelines to generate benefits for the enterprises to the greatest extent [1.222-1.225].

The reasons of unmet expectations can be related to disparate motivations. Among them, the literature underlines the great influence of the not deterministic behavior of business models [1.226], which complicates reengineering tasks. Ricondo and Viles [1.227] claim that unsuccessful experiences arise from the disregarded analysis of the current process limitations and the consequent adoption of business improvement initiatives mimicking other experiences. This mainly regards the introduction of lean practices with the objective of minimizing costs [1.213; 1.228]. The most frequent and harsh critique concerns exactly the strict focus on efficiency and technology and the disregard of people in the organization that is subjected to a reengineering initiative. Very often the label BPR was used for major workforce reductions with the aim to decrease organizational and production costs, instead of being able to suggest any kind of improvement based on process innovation. Moreover the analysis performed in [1.229] suggested that in order to obtain successful BPR initiatives, redesign efforts should be focused not only on cost and time reduction but mainly on the areas of the business process having the most direct impact on customer value. These results show how managers should reengineer their core processes starting from the customer perspective.

Methodologies to support BPR which take into account the customers' sphere are not absent and are documented in [1.230], which is an integral part of the present work. However, it is hereby disclosed that many of these approaches fail to establish a link between inputs and outputs of a business process, which is seen as a basic requirement for efficient BPR methods [1.231]. As a consequence, such tools suffer from limited applicability and arguable reliability.

The main strengths and weaknesses of traditional and customer-oriented BPR methods are then summarized in Table 1.2.

Table 1.2 Pros and cons of various kinds of BPR approaches

	Strengths	**Weaknesses**
Traditional BPR approaches	• Hints to redesign the business process at the operational level.	• Disregard of human-related factors; • Low flexibility to fit specific firm needs and consequent adoption of practices that have mimicked successful implementations experienced in other industrial contexts.
BPR methods focused on the customer's sphere	• Consideration of market rebounds determined by process modifications.	• Poor reliability due to the difficulties in schematizing the not deterministic behavior of business processes.

1.3.3 An overall vision about current limitations

The above analysis has elucidated shortcomings of existing methodologies, possible reasons of the missed transfer of proposals from academia to industry, failures caused by erroneous implementations. On the one hand, tools aiming at supporting Product Planning are either poorly systematic and lead to vague and unrepeatable results or integrate rigid structures and do not own enough flexibility to fit any industrial field or organizations' size and know-how. The consideration of customers' side is gaining popularity in R&D teams and within engineering design tasks, but it risks to become a strict guiding principle, leading to limit creativity and hinder radical innovation. At the same time, few proposals illustrate how to undertake motivated decisions during product planning, because of the lack of quantifiable measures and comparable evaluation criteria in the initial design stages.

On the other hand, the analysis of BPR approaches reflects the trajectories expected for the evolution of design science, i.e. the need to attribute greater importance to customers and to human demands. The methodologies for reorganizing the industrial processes seem to be characterized by the strict alignment towards either savings or customer satisfaction. Such a feature has to be overcome by attempting to safeguard both the recalled inputs and outputs of business processes. In this sense, the need of linking industrial activities with what is manufactured, offered and commercialized fits the exigency of a major integration between products and processes spheres, which have followed, at least up to now, distinct innovation patterns.

1.4 Contribution of the thesis and organization of the original contents

1.4.1 Summary of the contribution

The contribution of the present dissertation is a set of original instruments that aim at overcoming the critical issues reported in 1.3. More specifically, the objectives that the thesis attempts to pursue are basically fulfilled through:

- criteria to individuate the main factors that limit the competiveness of business processes and to consequently guide the innovation tasks towards the most suitable redesign activities;

- metrics to match the operations forming the industrial processes and the outcomes in terms of characteristics of the delivered products and services;
- methods to individuate the phases of business processes representing value bottlenecks;
- guidelines to successfully rethink the main peculiarities of deliverables in terms of the attributes participating to customer value;
- instruments for estimating the success potential of innovative products and services;
- a step-by-step methodology to select the most valuable product development alternatives.

Each achievement can be used singularly or in conjunction with other tools, since the instruments share the lexicon and several variables through which to determine the outcomes of the methods and the decisions to be tackled.

1.4.2 Potential users of the proposed toolkit

As already remarked, the development of the proposed toolkit follows the results of a state-of-the-art analysis of existing instruments to facilitate innovation processes in industry. In particular, efforts have been dedicated to lay bare the limitations of the investigated tools. The disclosure of these weaknesses has been performed according to literature evidences and some practical experiences of the candidate or his research group. Since the critical review has not been restricted to specific kinds of firms, the illustrated methods and approaches should be suitable in any industrial context.

The candidate is pronouncedly skeptical about the above conclusion. It will become apparent during the presentation of the toolkit that, despite attempts to propose simple tools, some skills and a deep knowledge of the reference industrial domain are required. Several small enterprises could have an excessively narrow vision of their industry by operating in local markets and offering products and services with an extremely market-responsive approach [1.232]. In many cases, little firms even designing, producing and selling their own artifacts act as third-parties upon the requests and specifications of major industrial players [1.233]. On the other hand, the proposed tools fit the exigencies of companies which autonomously undertake decisions about their products and processes without needing to meet the demands of other (and usually more powerful) industrial subjects. In other words, those enterprises having a small amount of customers on a B2B basis hardly feel the need to strategically redesign their processes according to internal inputs and, consequently, do not require to adopt reengineering tools like those proposed in this dissertation.

At the same time, many of the illustrated instruments are tailored for R&D or design teams having an accurate know-how about the distinguishing features of the market and the mechanisms governing internal business processes. The experts which are the perspective users of the proposed toolkit require thus an overall vision about the various inputs modifying the practices followed by the firm and the efforts paid by the company to reorient the market towards its deliverables. Usually, medium to large enterprises own design teams that supervise, in a more or less structured way, industrial activities ranging from picking up market inputs to introducing technological advancements to enhance the business process. Whereas market and technical departments are distinct units within the firm, many companies of the indicated size allow a continuous communication between the teams in order to update and revise projects and decisions. As an alternative, cross-functional teams with diversified competences are created to follow NPD projects [1.234].

On the contrary, big corporations and multinationals generally present R&D teams with very specific assigned tasks. Moreover, such teams are diffusedly geographically distributed [1.235]. The parceling of competencies represents an obstacle towards the formation of a general vision of the industry, which is needed for the employment of the integrated toolkit. As a result, corporations do not belong to the target enterprises expected to adopt the proposed approach.

1.4.3 Outline of the thesis

Coherently with the expected integration of product- and process-oriented approaches, the original contents of the present thesis will not be organized according to their suitability to support product development or process reengineering. A first attempt of integration concerns the analysis of firms' main weaknesses, which is claimed to guide towards the individuation of redesign priorities. These concern the main features and benefits characterizing the product, the ways the process phases are carried out or a mix of them.

Section 2 describes the proposed tool and its further developments. Such an instrument can be exploited by industrial organizations in order to identify the basic reasons of declining competitiveness and to undertake the most adequate measures.

However, not all the enterprises own the means for making comprehensive analyses of the business process, the market and the distinguishing factors of the offered products and services. Besides, some firms result reluctant in entrusting formal examinations the task of strategically defining the patterns of innovative projects. Indeed, the practice is quite diffused of skipping the "diagnosis" of own strengths and weaknesses and intuitively advancing innovation options in terms of enhanced processes or new products. The former can be experimented and higher performances, as well as minor costs, are easily assessed, so to choose the most beneficial process modifications. Conversely, as seen, the task is not sufficiently supported of choosing the most advantageous product profile, idea or concept among a set of given alternatives. Section 3 is dedicated to illustrate the candidate's proposal to perform the product selection. The advanced methodology stems from literature evidences which have been combined in order to obtain a model capable to identify the most beneficial product platform by limiting the impact of experts' and decision makers' subjective evaluations.

The original contribution is therefore structured according to different situations that organizations can face: the beginning of a deep review of the business process and the need to select innovative ideas regardless the method and the motivations that have led to their generation.

Section 4 concludes the thesis by summarizing the results and highlighting the main limitations to be taken into account for the candidate's future research activities.

1.4.4 Publications of the candidate within the field of the thesis and presentation of the original contents

Many fundaments of the toolkit and instruments which make part of it have been widely exposed in publications authored by the candidate and written during the PhD triennium (2011-2013). Other findings are reported in manuscripts that are currently under review for authoritative journals. Due to the acknowledgement of the scientific community with respect to the contents of the thesis, the candidates' publications and papers under review pertaining to such subjects [1.206, 1.217, 1.230, 1236-1.240] are attached to the dissertation and constitute an integral part of the work.

Figure 1.4 elucidates which Sections of the thesis and which attachments (or chapters of them) treat the developed instruments for innovation in industry, constituting the original proposal of the present work. The Figure clarifies, thanks to the legend at its top, where any reader of the dissertation can find suitable information about the background, the description and the application results for each module constituting the toolkit.

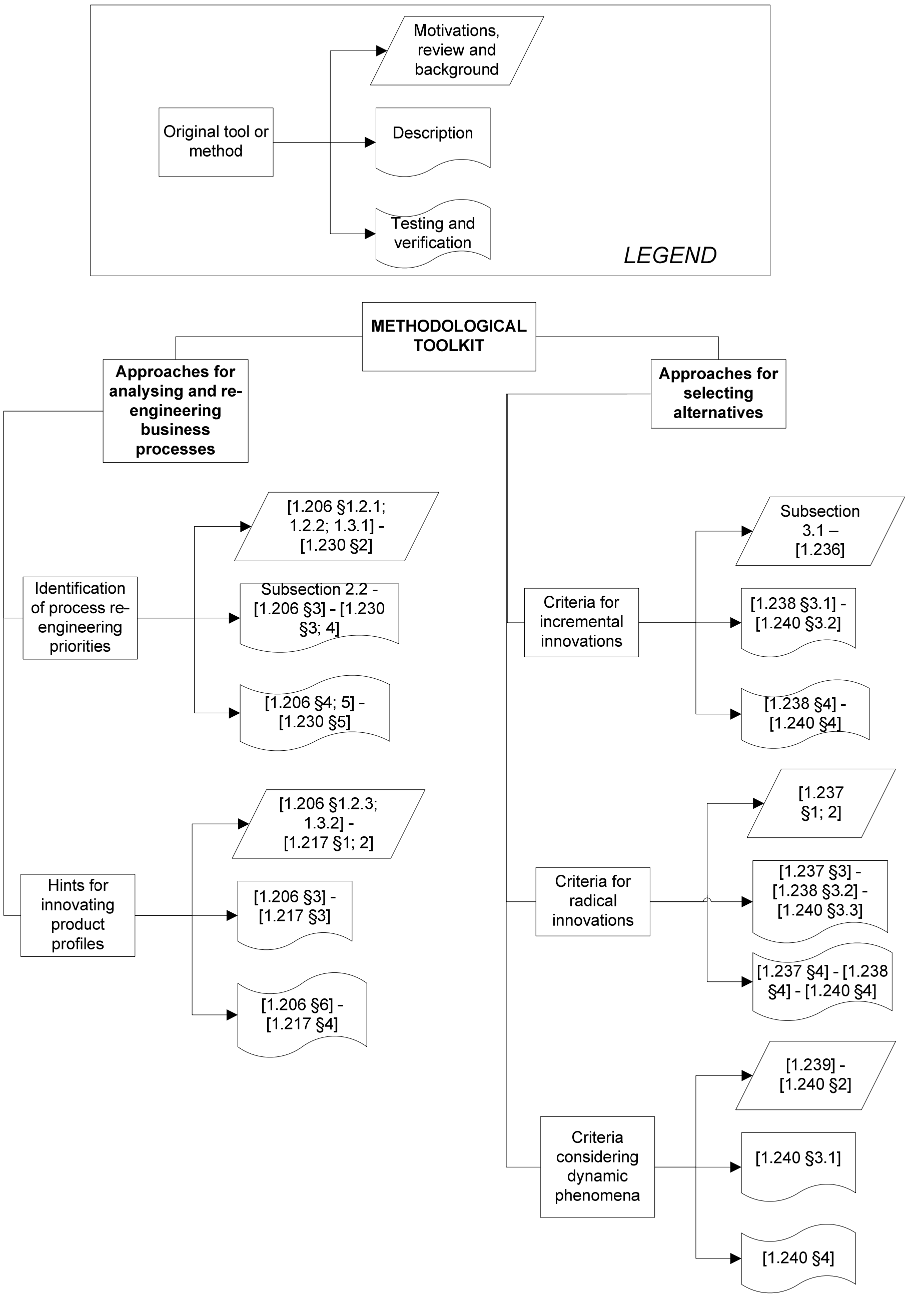

Fig. 1.4 Presentation of the original contents within the thesis and the attached manuscripts authored by the candidate

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2 Guidelines for the redesign of products and processes

The objective of integrating the reengineering approaches for products and processes is the fundamental theme of the present Section. More specifically, the contribution of the candidate stood in the fine-tuning of a general framework viable to guide companies in the individuation of the innovation activities owning major priority, namely Integrated Product and Process Reengineering (IPPR). The full description of the proposed toolkit is provided in [2.1], which is an integral part of the thesis.

Subsection 2.1 gives an overview of IPPR and pinpoints its utility, while further developments are outlined in Subsections 2.2. and 2.3. More in detail, they illustrate the methodological enhancements of the framework for establishing value bottlenecks in the business processes and identifying product innovation opportunities, respectively. Eventually, Subsection 2.4 introduces the open issues to be faced in the future work.

2.1 Insights of IPPR methodology to integrate product and process redesign

Each kind of business problem requires a specific approach to be treated and a careful analysis of the aspects that limit the competitiveness of industrial processes in light of the satisfaction of customers and other stakeholders interacting with firms' products and services. IPPR analyzes such problems through an integrated view, attempting to reveal the intertwining network of factors that participate to determine both industrial problems and the quality of firms' deliverables.

The basic element of the integrated analysis is the business process, conceived as the collection of activities and methods addressed at fulfilling the requirements of products and services which are capable to satisfy the expectations of customers. Such an interpretation is abundantly documented in the literature (see Subsection 1.2.1) and several efforts have been dedicated to develop approaches for supporting the decision tasks of CEOs, entrepreneurs and industry leaders, aimed at maximizing the performance of business processes. An extensive branch of the research has lead to the birth and diffusion of BPR (see

Subsection 1.2), which has received in the early 1990s a general appraisal from industrial advisors, besides the scientific community. Some decade later, this kind of instruments has conversely resulted in a great amount of flops or at least the outcomes of their application did not come up to the expectations of adopters. As already remarked, studies about the above failures revealed how the exceeding attention on savings about the internal processes and the consequent disregard towards the value of the offered products determined the inadequacy of BPR techniques.

In addition, the last years have witnessed the birth of tools dedicated to support the development of new products and particularly of strategies aimed at modifying the bundle of competing factors which characterize current artifacts. The objective is to fulfill latent and still unexpressed needs in order to achieve a consistent competitive advantage by rearranging the boundaries of the marketplace. The purpose is thus the generation of a so called New Value Proposition (NVP). However, at the current state of the research, the approaches dedicated to the creation of NVPs suffer from poor repeatability and difficulties in applying them systematically, as remarked in Subsection 1.1 for proactive product planning methods.

In this context, IPPR is proposed as a contribution to fill the gap by balancing the demands required to carry out industrial processes, as well as by enabling the development of innovative products characterized by unprecedented elements of value for end users or any involved stakeholder. The methodology orientates the choices to be made along reengineering activities, on the basis of value criteria, by answering to the following questions of managers:

- what should be changed in the business process, built as a sequence of industrial phases, in order to effectively fulfill customer requirements or even boost the perceived satisfaction?
- what should be changed in the mix of offered products and services, depicted as a set of attributes, in order to deliver superior value?
- which investments and business modifications should be prioritized for implementing the new design of the product or the process?
- which established methodologies and tools can result appropriate for the business transformation, according to the new ideas?

IPPR is articulated on two main layers in order to guide organizations towards acquiring all the elements to respond the above questions and especially to lead them towards assigning priority to the resulting answers. At the higher layer, firms analyze their competitive situation and individuate which industrial problems result the most constraining to thrive in the business world. In these terms, the problems are articulated in three classes (as shown better in 2.1.1):

- the need to shift towards more evolved technologies to fulfill posed requirements;

- the weaknesses of the business process in terms of generating value for customers with respect to the faced expenditures;
- deliverables that are no longer capable to produce attractiveness in the marketplace and hence the request of providing new benefits for the consumers.

At the lower layer, IPPR indicates the most suitable instruments to analyze a large range of products' and processes' facets in order to individuate manufacturing phases, organizational issues, business practices, characteristics of artifacts and services that need to be redesigned.

2.1.1 Classes of business problems

The problems encountered in industry arise from diversified causes, which encompass market, technological and organizational aspects. Besides this consideration, the essence of business problems differs according to the current stage of the typical historic cycle observed by products, which includes its birth, refinement and obsolescence. With reference to such succession of phases pertaining the product lifecycle, IPPR provides tailored criteria to address the innovation process of the three classes of business problems.

Typically, the birth of new products treasures the stimuli offered by the market or matured inside the organization. In other cases, changing exigencies, market perturbations or modified norms dictate the need to switch towards new product paradigms. In any of these situations companies face the problem to organize the business process in order to fulfill the novel, as well as the established product attributes with a minimum amount of investments. Whenever the attempts to design processes with the above characteristics result in unexpected undesired effects, products not compliant with the posed requirements or very poor profitability, IPPR suggests to analyze the system with the instruments tailored for the first class of business problems. Such tools originate from the approach described in [2.2] and referring to a tailored application of the methodology named Process Value Analysis (PVA).

The refinement stage of the product commonly observes long periods of incremental improvement, during which customer priorities or preferences consistently vary. This can result in scarce attractiveness for undiversified products long competing in the marketplace and consequent inadequacy of business processes that present bottlenecks along the value creation chain. The second class of business problems targets the difficulties encountered by the firms willing to reengineer their industrial process in order to stay competitive. The original schema of PVA [2.3] is exploited in this case, since such an approach is aimed at revealing value bottlenecks of business processes.

Eventually, after their maturity, products evolve towards the adoption of more sophisticated technologies or the fulfillment of additional needs, giving rise to new generations of physical artifacts or intangible services. IPPR instruments recommended for the third class of business problems aim at conceiving products overcoming established frameworks and offering superior value for customers.

2.1.2 IPPR methodology: a common logic for different problems

Besides providing tailored tools for each class of the problem, IPPR adopts a common logic to guide towards beneficial solutions, which is, in turn, articulated in three main phases:

- the analysis of the business process with the codification of the relevant information (Process to problem);
- the highlighting of the system criticalities (Problem to Ideal solution);
- the individuation of the most appropriate solving paths (Ideal solution to Physical solution).

The purpose of the first step is «to obtain an exhaustive description of the as-is situation by investigating the industrial operations and their outputs. The result of this phase is constituted by a model of the business process capable to represent all the aspects related to both the functional and economic domains. Such a multidimensional approach allows to manage the cross-disciplinary nature of the business process. This is the key feature enabling a comprehensive analysis of a large amount of common industrial problems».

The following step, i.e. Problem to Ideal solution, «is focused on the clear identification of the value bottlenecks and eventually of potential innovation opportunities. Moreover, once the critical aspects of the business process have been analyzed, proper reengineering actions are defined in order to remove the value bottlenecks and preserve or regain the market competitiveness. These guidelines are expressed in the form of new process requirements for the problems belonging to the class 1 and 2, while they are depicted as directions for the transformation of product profiles, with reference to the class of problem 3. The emerging hints represent the inputs of the subsequent design activities which are aimed at identifying suitable technical solutions for the implementation of the ideas of the new process or product».

Finally, the conclusive stage of the methodology «suggests the suitable and acknowledged instruments to support the design activities of the physical solutions concerning the introduction of new industrial process phases, the improvement of the existing ones, the reorganization of the resources allocation programs, the production of innovative items and the delivery of novel services» [2.1, §2.2].

Whereas the articulation of IPPR in three basic steps constitutes the backbone of the methodology, each phase encompasses a set of constituent activities. A sample of techniques is suggested to perform each task, among which widespread and acknowledged systems and instruments to support the design of products and processes, e.g. IDEF schemes [2.4], Theory of Constraints [2.5], Theory for Inventive Problem Solving (TRIZ) [2.6], Kano model of attractive quality [2.7], Value Engineering [2.8], Four Actions Framework belonging to the toolkit of Blue Ocean Strategy [2.9]. Original tools are likewise proposed within IPPR to support the analysis of the industrial process, to pick out the most pressing reengineering priorities, to aid the search of new business opportunities.

Nevertheless, each task can be carried out through alternative instruments employed to design products and processes. Hence, any IPPR practitioner can leverage his/her own body of knowledge according to his/her competencies within process reengineering and NPD, thus customizing the toolkit of the methodology. In order to cope with individual approaches to face the problem, IPPR clearly defines the required information to be mapped (or to be fully disclosed in case of missing knowledge) in order to correctly manage the business process and its innovation. Particular attention has to be paid to highlight any typology of resource employed by the company to carry out the business process, including expenditures, technologies, labor and required time. The identification of the whole range of product attributes that are fulfilled by means of the monitored process hold not minor importance. In order to correctly represent the thorough amount of information, IPPR recommends ad hoc models and formalisms, which furthermore allow to underline how the resources are exploited to generate value for customers.

The classes of problems share to a large extent the elements of knowledge requested to carry out the steps of the methodology, whose completion leads IPPR users to the identification of feasible process/product innovations. Further information is however required in each situation pertaining to the market and the customer perceived satisfaction.

2.1.3 The industrial case studies faced by means of IPPR

The employment of the methodology and its suggested tools are illustrated in [2.1] for three different industrial processes, exemplifying each one the business problems related to a specific class. The explanation of how IPPR has been applied in a step-by-step fashion favors the reproducibility of the approach in any context. The case studies belong to strongly diversified business areas, namely the pellet manufacturing, the production of fashion shoes, the design of professional blow dryers.

In all the examples IPPR demonstrates its capabilities to individuate redesign priorities and consequently valuable innovation patterns. This witnesses the flexibility of the methodology with regards to the variety of business problems that can be encountered in the industrial world.

More in detail, the identification of value bottlenecks for the manufacturing of wood pellet (first class of problems) has revealed the urgency to introduce new technologies capable to reduce energy consumption during the manufacturing process. The individuation of the process criticalities and the reasons behind their shortcomings have matched hypotheses presented in the literature. Subsequent research has allowed the design of an innovative system for the milling of wood biomass, which is actually patent pending [2.1, §4].

With respect to the experiment concerning an Italian footwear district (second class of business problems), the application of IPPR has led towards the disclosure of least performing process phases according to the value generated for customers and required resources. The core suggestion emerged by the application of the methodology is the adoption of quick response strategies to boost competitiveness, by allowing also shoe factories not working for famous brands to offer very fashionable footwear items. In addition to converging indications about the profitability of quick response policies with respect to different geographical areas, a prototype implementation for an enterprise belonging to the industrial district has provided evidence about the advantages of the reengineering strategy suggested by IPPR [2.1, §5].

Eventually, IPPR application to the domain of professional blow dryers (third class of business problems) has resulted in a new product profile, swiveling on unprecedented elements of value for the end users, i.e. the stylists. The consensus about the new concept for hairdryers to be employed in beauty salons has emerged through a survey, which has further highlighted also a preferred embodiment for the technical solution [2.1, §6].

2.1.4 Usability of IPPR and expected benefits

The reported examples draw attention to the beneficial support of IPPR along innovation initiatives. From a managerial viewpoint, IPPR is capable to circumscribe the advantageous directions for business rethinking, thus avoiding waste of resources in developing not valuable innovation ideas. The rapid discarding of not favorable reengineering options results a crucial issue in the industry, given the multitude of innovation tasks failed during the development process and the vast amount of new products resulting in commercial flops.

Besides supporting all the stages of process and product development tasks and addressing towards technical and organizational solutions, IPPR steps allow to perform a dynamic mapping of the enterprise across the dimensions pertaining the firm, the commercial offer, the customer perception of value. In this sense, also thanks to the ease of use characterizing the methodology, IPPR can be seen as a real-time decision support for managers, entrepreneurs and policy makers.

By using the proposed models devoted to represent and analyze the process and the product, the detailed investigation of the firm activities supports the company in mastering value bottlenecks, main criticalities of the enterprise, reengineering priorities. Moreover, the original instruments supposed to stimulate creativity within NVP projects permit the company to uncover potentially fruitful business opportunities.

2.2 Uncertainty issues in process reengineering

Among the criticalities that affect the original IPPR framework, as remarked in [2.1, §7.2], the analysis of business processes does not consider possible misalignments between experts' evaluations. In addition, the variables that participate to provide a quantitative evaluation of the process phases, so to identify value bottlenecks, are characterized by variability and by not deterministic behaviors. The problem that emerges, in this sense, is to manage uncertainties about the inputs of the procedure and the outputs employed to undertake decisions about the process segments requiring major redesign. Tables 2.1 and 2.2 summarize the above inputs and outputs with regards the PVA logic [2.3], which constitutes the basic reference for process reengineering with IPPR.

With respect to the obtained results, each phase is placed in a quadrant of the VAC diagram (step 8), according to the magnitude of *VE* and *VE* values (step 7). The quadrants and the suggested reengineering actions for the phases falling in such areas of the graph follow:

- Area of Low Value (low *VE* and *VN*): such phases are demanded to deliver novel functions and should be radically restructured in order to drop their resources consumption or even trimmed and substituted by existing process segments;
- Area of Basic Value (low *VE* and high *VN*): the phases falling in this quadrant are oriented to fulfill the fundamental attributes and do not necessarily require investments;

Table 2.1 Roadmap of the PVA methodology: inputs and their explanation

Step	Task	Outcomes	Procedure inputs	Explanation of the variables
1	Information gathering	Process model, individuation of the attributes that characterize the business, sizing of expenditures relevant to each phase	List of phases; list of customer requirements (CRs)	**Phases**: set of segments in which the business process is articulated **Customer requirements**: set of product characteristics that are fulfilled by means of the process and that participate to generate users' value
2	Evaluating the reasons of satisfaction and discontentment	Characterization of the CRs according to their orientation in determining expected or exciting quality	Kano categories	**Kano categories**: valuable quality attributes, according to Kano model, pertaining to each CR (to be chosen between *must-be*, *one-dimensional*, *attractive*)
3	Estimating the role played by product and service attributes	Characterization of the CRs according to their impact within the commercial offer; consequent determination of their share in terms of customer (dis)satisfaction	Relevance indexes *R;* Customer Satisfaction (*CS*) and Dissatisfaction (*CD*) terms	**R**: degree of importance pertaining to each CR with respect to the global perception of customer satisfaction (to be attributed though a Likert-type scale ranging from 1 to 5) **CS/CD indexes**: extents of the capability of each CR to excite customers (CS) and avoid severe dissatisfaction (CD)
4	Relating the internal sphere of the process with the business outputs	Estimation of the contribution provided by process phase in fulfilling the CRs	Correlation coefficients k_{ij}	$\mathbf{k_{ij}}$: fraction of the contribution of the *j-th* phase to fulfil the *i-th* CR
5	Measuring the phases expenditures	Extent of employed resources, emerging harmful effects, auxiliary functions, costs and time necessary to carry out the phases	Phases resource indexes *RES*	**RES**: fraction of the resources consumed by of each phase, intended as any obstacle to process competitiveness

Table 2.2 Roadmap of the PVA methodology: outputs and their explanation

Step	Task	Outcomes	Procedure outputs	Explanation of the variables
6	Measuring the process outputs from customer viewpoint	Benefits delivered by each phase in terms of avoided dissatisfaction and customer contentment	Phase Customer Satisfaction (*PCS*) and Dissatisfaction (*PCD*) coefficients	**PCS**/**PCD**: contribution of each phase within the scope of exciting customers (PCS) and avoiding severe dissatisfaction (PCD)
7	Comparing the delivered benefits and the internal expenditures	Ratio between the terms expressing satisfaction and the phase consumed resources	Value for Exciting requirements (*VE*) and the Value for Needed requirements (*VN*) coefficients	**VE**/**VN**: efficiency of each phase in terms of their capability to excite customers (VE) and avoid severe dissatisfaction (VN)
8	Summarizing the results	Comparison of phases value, highlighting of the bottlenecks	Value Assessment Chart (VAC) graph	**VAC** graph: diagram representing the phase with respect to VE/VN pairs, hence highlighting process bottlenecks in a graphical format

- Area of Exciting Value (high *VE* and low *VN*): the phases belonging to this Area are worth of investments in order to maximize their generated benefits; their success is a key to let the product/service differentiate from the competitors;
- Area of High Value (high *VE* and *VN*): the phases of this quadrant are to be safeguarded.

In order to consider the variability of the coefficients and the uncertainties affecting the decisions when multiple analyses are performed, a Monte Carlo simulation approach has been integrated. The methodological upgrade is reported in [2.10], which represents an integral part of the present thesis.

The simulation is applied to the inputs presented in Table 2.1, so to generate arrays of values (with the same size) which follow an assigned probability distribution function, according to the outcomes of experts' analyses. The outputs presented in Table 2.2 are linked with the inputs of Table 2.1 by means of mathematical relationships. The same formulas are applied for each row of said arrays in order to generate vectors containing varying *VE*/*VN* data and to consequently build VAC diagrams representing the uncertainty.

Figures 2.1 and 2.2 illustrate the analysis of an industrial process for the manufacturing of pharmaceutical tablets, by using the original PVA and its upgraded version described in [2.10], respectively.

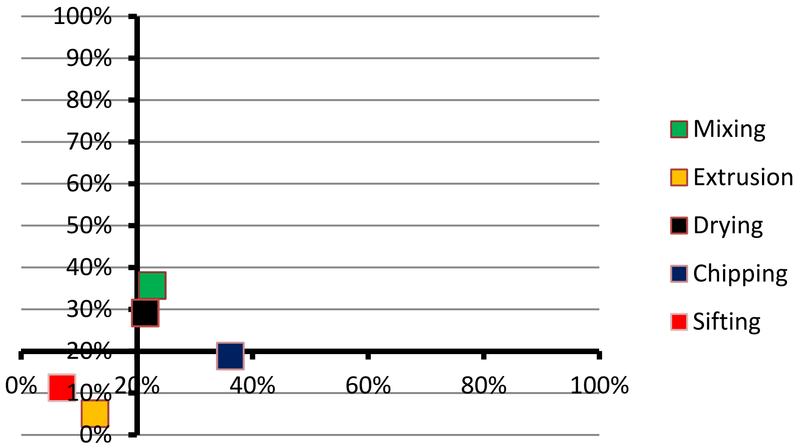

Figure 2.1: analysis of a pharmaceutical process by means of the original PVA applied by an industrial expert

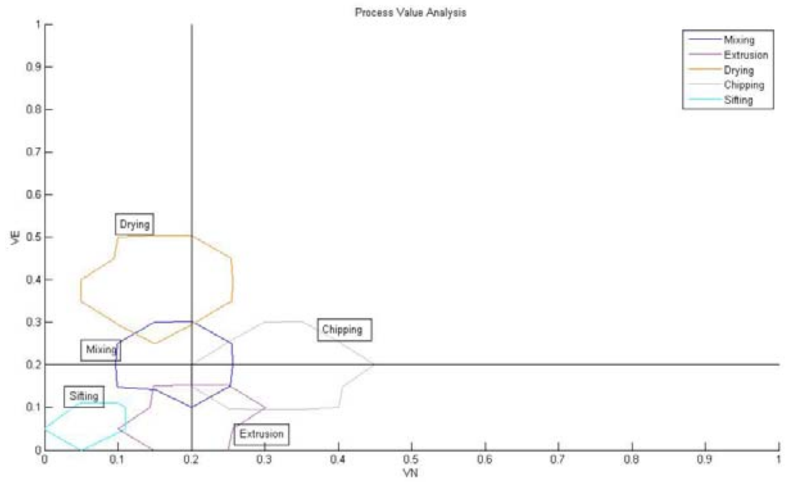

Figure 2.2: analysis of a pharmaceutical process by means of the updated PVA applied by a plurality of industrial experts

It is straightforward noting that any organization can infer the risk in undertaking any reengineering action from Figure 2.2. Conversely, the results obtained by using original PVA methodology can just individuate the most suitable measures for modifying (if appropriate) any phase of the business process.

The contribution [2.10] provides all the means for performing the simulations, including the references for a software application developed by the candidate to ease the task. The work illustrates two case studies to evaluate the applicability and the reliability of the upgraded PVA. The new methodological framework represents, thanks to the enhancements, a preliminary hypothesis for a candidate module of a decision support system aimed at guiding industrial subjects from process analysis up to the individuation of the most proper practical measures to redesign its business.

2.3 Supporting value innovation with the guidelines

IPPR framework employs the New Value Proposition Guidelines (NVPGs) to face the industrial problems of the third class, i.e. the need to radically rethink the benefits delivered by offered products and services. Such Guidelines represent hints for redefining the valuable aspects of the commercial offer, indicating the kinds of the most favorable modifications (e.g. introduce new functionalities) and the transformations to be maximally avoided (e.g. introduce an undesired effect within the system) [2.1, §3.3.2]. However, as remarked in [2.1, §7.2], the suggestions for products redesigning may appear too vague and abstract. In this sense, the contribution of the candidate and the research group stood in enforcing the reliability of the guidelines and better specifying the changes expected to favor success. The insightful analysis of the case studies used to support the validity of the BOS [2.9] and a more precise characterization of the transformed customer requirements led to a more advanced definition of the NVPGs. The work is described in the contribution [2.11], which is an integral part of the dissertation.

The emerging suggestions are supported by a statistical analysis, assessing the robustness of each guideline. The recommendations are explicitly enunciated in [2.11, §4.2, 4.3.2, 4.3.3]. The indications converge with the innovation patterns followed by other successful artifacts, not included in the sample of initially examined case studies.

2.4 Open issues regarding the developed toolkit: ongoing and future work

Previous Sections have highlighted the benefits for industrial practitioners to employ IPPR for guiding innovation processes and its modules leading to advantageous solutions for new processes and products. Further on, the developments of the specific tools allow an increased reliability of the approach and a better support to guide towards business reengineering. The task is then supported of individuating the business areas requiring major attention through an integrated analysis of products and processes and proposing suitable techniques to face diversified industrial problems.

However, a full validation is not concluded, since it would require additional applications. Indeed, although combining the knowledge and the capabilities of recognized methods and tools, as well as suitable strategies to solve specific business problems, the proposed toolkit requires more tests in industrial contexts. This is especially true for assessing the benefits of NVPGs, whose more advanced version has observed just convergences with literature evidences, but has not been employed yet to proactively ideate radically innovative products. In this sense, the candidate is involved in further research activities carried out by the research group and aimed at experiencing methods for innovative product planning. Such methods swivel on the success factors characterizing past experiences, described according to a variety of taxonomies. The final objective is fully guiding designers towards innovative product profiles by consistently reducing the solution space according to a plurality of criteria. Ultimately, whereas the preliminary experiments have demonstrated the applicability of IPPR, the production of positive outcomes in different industrial contexts represents the target for statistically proving the goodness of the framework.

With respect to methodological aspects, a major development is expected within the analysis of business processes and their deliverables. The presented techniques allow taking into account the accomplished product attributes and the extent to which process phases contribute to their fulfillment, but disregard the level at which customer demands are satisfied. Such a limitation is expressly recalled in [2.1, §7.2] and a hypothetical way to face the problem is exposed in [2.12]. The same need has emerged during the ongoing research project ICT4Shoes, funded through Regional operational program Objective "Regional competitiveness and employment" of the Tuscany Region (Italy) and co-funded by the European Regional Development Fund for the period 2007-2013 (POR CReO FESR 2007-2013). More in-depth studies conducted by the candidate [2.13] have individuated a reference model for linking the quality level to which customer requirements are fulfilled and the amount of arising satisfaction [2.14]. The integration of a quantitative equations relating performances and the amount of arising benefits is currently in an experimental phase. Anyway, the acquisition of customer opinions about the perception of each product attribute is viable to provide more rigorous results emerging by employing the PVA (especially for problems belonging to the second class of IPPR). More specifically, this measure can potentially decrease uncertainties about the final outputs of the updated version of PVA, by generating *CS*/*CD* indexes with reduced variance (see Step 3 of Table 2.1). The reference formulas linking the degree to which competing factors are achieved and the resulting satisfaction are besides exploited to fine-tune tools for supporting decisions about design alternatives, as illustrated in Section 3.

Another ongoing activity concerns the introduction of more systematic criteria to quantify the resources exploited by the business process and its phases (see Step 5 of Table 2.1). The extent of the consumed resources basically includes costs, times required to perform the industrial activities, impacts of undesired effects. Whereas the first two items are precisely assessed when business processes are correctly monitored by firms' management, the last term requires indirect measures. The proposed approach exploits the notions of Life Cycle Assessment (e.g. [2.15]) for measuring the ecological footprint of the phases, the supply chain, the employed technologies and materials. Besides providing more reliable estimations of the terms employed within the PVA, the improvements aim at building suitable methods for firms wanting to carry out more sustainable processes and offering greener products [2.16].

The planned improvements need to be treasured in order to systematize the analysis module for a wider decision support tool aiding BPR initiatives, as outlined in Subsection 2.2.

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3 Value-oriented tools for choosing the most promising innovation options

As already clarified in the Introduction section, decisions influence to a great extent the success of reengineering initiatives. Companies commonly own the means to evaluate the benefits of new processes, technologies or managerial choices in terms of their rebounds on the quality of the deliverables and the costs of the operations. In other terms, once two (or more) alternative process models have to be compared in order to perform a selection, the firms can measure the efficiency of the options and choose what favors profitability and what better fits the scopes and the mission of the enterprise. Conversely, product development projects are characterized by doubts and uncertainties, especially in the initial design stages, due to qualitative factors to be accounted. In this sense, the candidate carried out a research activity aimed at better supporting decisions to be tackled during product planning, more specifically the selection of ideas described through their distinguishing features.

Besides combining findings from different contexts, the advanced proposal can be suitably employed when the selection takes place within a sample of radical and incremental innovations. The usefulness of the present decision support tool stands in the frequent situation faced by organizations, in which product development presents proposals with varying degrees of innovativeness. Such a trait undoubtedly constitutes an element of originality with respect to the previous state of the art, as underlined in [3.1 §2; 3.2 §2], which constitute an integral part of the thesis. Said chapters of the cited manuscripts provide an overview about decision methods diffused within engineering design and highlight their limitations with respect to the objectives of the present research. The motivations behind the creation of a quantitative method are likewise illustrated.

More in detail, the proposal illustrated in this thesis leverages the differences between radical and incremental innovations in terms of:

- the distinct ways they impact customer value;
- the diverse categories and factors to be considered in order to forecast their success;
- the points of product evolution cycle in which they most probably achieve success.

The structure of Section 3 is organized as follows. Subsection 3.1 analyzes the approaches dedicated to measure the expected customer satisfaction, which is an appropriate proxy to evaluate the validity of incremental innovations. Subsection 3.2 points out the contribution of the candidate in the determination of means for estimating the success potential of drastic product redesigns, hence a suitable metric for estimating the goodness of radical innovations. Subsection 3.3 discusses the possible role played by product evolution trajectories on the definition of more reliable decision support systems. Subsection 3.4 describes the proposal for selecting the most beneficial alternative within a set of products ideas. Eventually, Subsection 3.5 focuses on the open issues to be treated in the future research.

3.1 The assessment of customer satisfaction to evaluate moderate performance changes

Incremental innovations take place in periods of relative stability of technology and market, consisting in restrained modifications of products' reference performances [3.3], pushed by an increased efficiency of industrial processes [3.4]. More precisely, the literature associates the benefits provided by process management practices, gradual changes observed through incremental innovations, focus on existing customers [3.5]. In this context, the scientific areas and the methodological approaches aimed at achieving quality and customer satisfaction are the most appropriate for providing the means to evaluate incremental innovations and, as a consequence, support decisions.

The field of TQM represents therefore the discipline offering the most valuable tools to hit the target. The methodologies pertaining to TQM are consistently market-oriented and grounded on customers' opinions. Regardless the direct implementation of TQM practices, the exploitation of consumers' surveys and the objective of achieving customer satisfaction has become a diffused practice in engineering design and manufacture [3.6-3,8]. As a result, companies strive to identify (and consequently to fulfill) combinations of product and service characteristics mostly impacting the final value of what is offered in the marketplace [3.9].

The approach followed in the present thesis will explicitly use, as a proxy to characterize the goodness of incremental innovations and to select alternatives, the capability to satisfy customers as a result of the performances attained for each product attribute [3.1 §2, 3.1; 3.2 §3.2]. Within the present work, according to the posed objectives for the proposed decision making, it is required to assess customer satisfaction through quantitative terms. The nature of the satisfaction/performance relationships is however argued and the task of identifying the most reliable link is a severe challenge.

At first, many scholars (e.g. [3.10]) call into question seeded techniques that, like Importance-Performance Analysis (IPA), assume a linear relationship between the quality of product attributes and the perceived customer satisfaction. The hypothesis of proportionality is however denied by the acknowledged notions of the already mentioned Kano model and theory [3.11]. Plenty of contributions recognize the presence of the non-linear effects envisioned by the model and build sophisticated models to assess customer satisfaction for disparate purposes [3.12-3.14].

The candidate has therefore performed a survey of Kano' s model and its developments to identify the most suitable metrics to accomplish the task of assessing customer satisfaction and tackling decisions about incremental innovations. The next Subsection highlights deficiencies and open issues, which warn about the extent of reliability in using quantitative models to link satisfaction with the level of attainment of product attributes. Subsequently, Subsection 3.1.2 explains the motivations for the selection of the proposal advanced by Wang and Ji [3.15], as anticipated in 2.4.

3.1.1 Open issues hindering the employment of techniques based on Kano model

3.1.1.1 General aspects of the model

Kano model is classically applied as a tool to analyze the relationships among the product attributes and the resulting satisfaction of customers ascribable to a given market segment. In brief, a certain amount of customers is asked about their feelings when a given product attribute is fulfilled (functional question) or absent (dysfunctional question), as shown in the illustrative example reported in Figure 3.1.

Shoes are comfortable	☐ I really like it ☐ It must be this way ☐ I don't care ☐ I can tolerate this ☐ I dislike it
Shoes are not comfortable	☐ I really like it ☐ It must be this way ☐ I don't care ☐ I can tolerate this ☐ I dislike it

Fig. 3.1: illustrative functional and dysfunctional questions of Kano surveys

The combination of answers provided by each potential customer give rise to the designation to a Kano category (or quality attribute) for each investigated property. Besides answers with doubtful meaning, such quality attributes stand in:

- one-dimensional features, which generate excitement if the performance is high and cause dissatisfaction if unfulfilled;
- must-be features, which can just contribute to avoid dissatisfaction;
- attractive features, which are just capable to arouse excitement if fulfilled;
- indifferent features, playing a scarce role in determining customer satisfaction.

The quality attributes describe, in a qualitative way, different curves depicting the relationships between quality and perceived satisfaction, as classically represented in Figure 3.2.

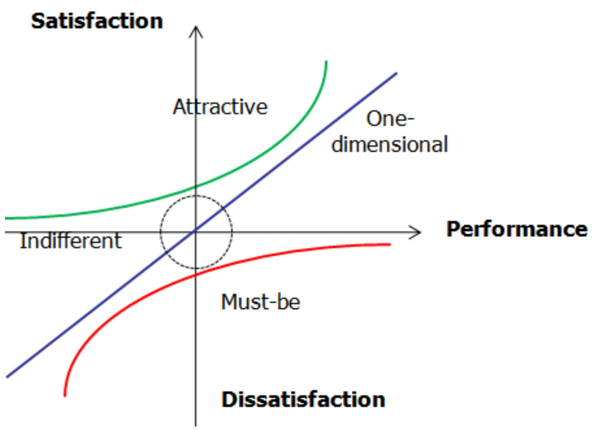


Figure 3.2: quality attributes of Kano model and performance/satisfaction curves

Each product characteristic is assigned the most representative Kano category; the designation is generally performed by considering the one resulting by the majority of customers [3.16]. In addition, each attribute is characterized by two quantitative terms representing different dimensions of relevance within the generation of customer satisfaction (see Subsection 3.1.1.4).

However, literature contributions provide different interpretations about peculiar aspects of the model and with regards to the exploitation of customer surveys. With respect to the candidate’s knowledge and on the basis of the retrieved material, the present state-of-the-art attempts to elucidate the most conflicting features, in order to highlight the possible pitfalls about the exploitation of Kano model for supporting decisions.

3.1.1.2 Administration of questionnaires and the exploitation of the results

The gathering of customer opinions and their consequent use to classify quality attributes represents a first point of discussion among scholars. In order to obtain sounder feedbacks from customer surveys, Larsson-Witell and Fundin [3.17] claim the need of monitoring the modification of Kano categories with respect to the growing accumulated experience of service recipients as the time of adoption progresses, which is confirmed by the insightful research reported in [3.18]. The potential uncertainty about the possible answers to be given by interviewed customers represents the focus of Lee and Huang [3.19], that propose fuzzy questionnaires to reduce the subjectivity of investigations conducted to identify the appropriate Kano categories for the product attributes. Similarly, fuzzy sets theory is used in [3.20] to overcome vagueness of Kano questionnaires with respect to the imprecise linguistic definition of customer requirements and the discrete choices in charge of respondents with regards to the levels of perceived satisfaction. The problem of uncertainty and variability of customer answers according to their census and individual preferences is treated in [3.21], which presents a method to simulate the missing responses of the consumers. Wu et al. [3.22] extended the classical questionnaires by asking the customer the perceived satisfaction level with reference to the current degree of product performance. The work links Kano model and IPA, aiming at identifying key success factors for achieving customer satisfaction. Product features are represented not just in terms of the quality categories, but also from the viewpoint of the worthiness of investments dedicated to enhance their offering level. Further modifications and extensions of the set of quality attributes are witnessed in the literature [3.23-3.24], but they have not faced, up to now, extensive consensus or diffused adoption.

The determination of Kano categories represents an additional issue on which many scholars have advanced proposals. The state of the art paper authored by Mikulić and Prebežac [3.25] offers a broad survey about the subject. It reveals that the approach proposed in the original Kano model, descending from the surveys including functional and dysfunctional questions, outperforms procedures commonly employed for supporting decision-making or borrowed from different disciplines. However, attempts to improve the assessment process with different strategies are still under development, as witnessed by Lin et al. [3.26]. This contribution proposes to enhance the approach with dummy regression for attributing the appropriate Kano category by emphasizing the property of changing slopes of the performance-satisfaction curves depicting must-be and attractive attributes.

3.1.1.3 Evaluating the importance of customer requirements in applications of the Kano model

In addition to the assessment of the quality attributes, the importance of the customer requirements is claimed to allow the quantitative measurement of customer satisfaction [3.27-3.28], and consequently a significant factor for identifying product development priorities.

Many scholars individuate a basic dependence between Kano categories and importance rates, with must-be attributes being the most crucial customer requirements in light of the overall satisfaction of the clients (e.g. [3.29]), but other kinds of relationships are discussed in the literature. Arbore and Busacca [3.30] acknowledge the non-linear relationship between performance and overall satisfaction for the banking industry and claim that previous models have been just capable to determine a mean value of attributes importance without a clear picture about the most urgent measures to attain customer satisfaction. According to the fundamental concepts of Kano theory, the scholars develop a regression model which is viable to remark the most important aspects to be addressed for safeguarding the share of satisfied customers and the main weaknesses causing the greatest discontentment. Tontini and Picolo [3.31] clarify the need to take into account the asymmetric nature of must-be and attractive customer requirements when determining the most impacting improvements to be carried out. Indeed, great importance could be otherwise attributed to product or service features exhibiting a marginal extent of satisfaction increase.

Apart from any supposed interplay between Kano categories and importance scores, the assessment of both aspects is worth to be conducted according to several contributions. Grigoroudis and Spyridaki [3.32] integrate their developed method, named Multicriteria Satisfaction Analysis, and Kano theory to infer the relevance of product attributes in engendering customer satisfaction and loyalty. However, the most common strategy to determine both the kind of quality attributes and their relevance is to conduct distinct customer questionnaires, aimed at revealing separately both aspects [3.33-3.35].

3.1.1.4 The quantitative nature of customer satisfaction and dissatisfaction

In a diverging perspective with respect to advocates of the need to individuate both Kano categories and relevance of competing factors, several scholars interpret the importance of product/service attributes as the rate of potentially satisfied and unsatisfied respondents to customer surveys. More specifically, the amount of must-be, one-dimensional and attractive designations for a given product attribute is considered as a proxy of its capability to generate satisfaction or avoid customer discontent due to the absence of expected characteristics or performances. Several contributions provide a quantitative support for these two complementary aspects, by building the “Better” (or “extent of satisfaction”, CS) and “Worse” (or “extent of dissatisfaction”, DS) coefficients, as originally described in [3.16].

Matzler and Hinterhuber [3.36] use the above indexes as metrics to determine the most impacting customer requirements within the implementation of Kano model concepts into QFD. CS and DS coefficients are exploited to build House of Quality applications characterized by budget constraints [3.37] or for product optimization purposes [3.38]. The discussed extents are graphed in [3.39] in order to highlight similarities among sets of product attributes, previously built according to the fulfillment of common needs at a higher abstraction level.

CS and DS are used also in [3.40] to determine a general value of importance within a QFD application aimed at designing simultaneously multiple product platforms. The literature witnesses proposals in which the coefficients are modified [3.41] or combined [3.42] with the objective of prioritizing customer requirements and improvement directions.

Eventually, an approach is proposed by Xu et al. [3.43] that takes into account both importance issues and the meaning of CS and DS coefficients. The scholars employ the overall relevance of customer requirements and tailored extents of satisfaction and dissatisfaction to build a diagram, designated as A-Kano model, claiming to better support product development decisions. The graph plots dots corresponding to product attributes, showing if they are positioned in the representative areas of attractive, must-be, one-dimensional or indifferent quality factors.

3.1.2 Chosen model to link quality and satisfaction

The preceding review highlights that, despite the disparate employments of Kano-wise tools and notions, alternative hypotheses have not gained acknowledgement up to now with respect to:

- the shape of the curves characterizing the relationship between satisfaction and performance according to each kind of quality attribute (Figure 3.2);
- the way to conduct surveys to achieve customers’ opinions;
- the way to attribute Kano categories according to customers’ answers;
- the need to substitute CS/DS indexes with importance assessments.

According to the above evidences, the model that the present thesis requires to assess incremental innovations, has to be found among the quantitative interpretations of the, otherwise qualitative, Kano curves. Nevertheless, it has to be taken into account that any chosen model relating quality and perceived satisfaction can result erroneous according to the variety of the arguments raised in the literature.

The comparison among available quantitative Kano models is performed in [3.44], which represents an integral part of the dissertation. The framework proposed in [3.15] has been selected, because of the independence from additional information with respect to what is provided through Kano surveys and the capability to represent historical variations of quality attributes.

The exploitation of the model for the scopes of ranking incremental innovations is widely explained in [3.1 §3.1; 3.2 §3.2]. The assessment strategy gives rise to a quantitative term, namely *appreciation level*, estimating the expected benefits of incremental innovations with reference to what is offered in the marketplace.

3.2 The evaluation of success chances for major product redesigns and its implications to support decisions

The review of product planning methods, presented in Subsection 1.1.2, reveals the difficulties in aiding the generation of radical innovations characterized by the introduction of new valuable attributes. Even more markedly, as highlighted in 1.1.2.6, decisions in the Fuzzy Front End of product development cycles are poorly supported.

Such a research gap has been treated by the candidate and his research group, leading to the exploration of past experiences about radical innovations facing either acknowledged success or unquestionable failure. The taxonomies through which to describe the innovative elements of new value profiles reflect those employed for generating the NVPGs (Subsections 2.3). The initial dataset of analyzed case studies has been expanded so to include additional successful experiences and a brand new sample of innovation failures.

The complete list of innovative products and services is shown in Table 3.1, which includes the industrial field of each example and indicates the attainment of success or the market flop.

All the treated innovations have been examined, thanks to literature documents, with respect to the reference industrial standard at time of business introduction. The deviations have been classified according to twelve typologies of modifications. Further details about the kinds of transformations can be found on [3.2, §3.3]. The twelve clusters are listed in Table 3.2, which provides illustrative examples for each circumstance in order to clarify when such kinds of transformations take place.

Table 3.1: analyzed radical innovations to infer rules for computing success chances

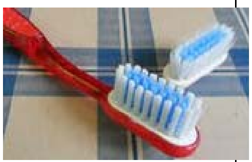
Commercial name	Industrial field	Success or failure
[Yellow Tail] wines	Food & Beverages	Success
Amphicar	Automotive	Failure
Apple Ipod	ICT	Success
Apple Lisa	ICT	Failure
Apple Newton	ICT	Failure
Barnes & Noble booksellers	Retailing	Success
Bert Claeys Kinepolis	Entertainment	Success
Bloomberg	ICT	Success
BMW C1 motorbike	Automotive	Failure
Body Shop cosmetics	Retailing	Success
Bratton's New York Transit Police	Public services and defense	Success
Cadillac Cimarron	Automotive	Failure
Callaway Golf "Big Bertha"	Sport and fitness	Success
Campbell’s Souper Combo	Food & Beverages	Failure
Canon copiers	Electronic devices	Success
Cirque du Soleil	Entertainment	Success
CNN	Entertainment	Success
Compaq in Server Industry (1992-1994)	ICT	Success
Croc's	Apparel & footwear	Success
CueCat	ICT	Failure
Curves fitness company	Sport and fitness	Success
Dell’s Web PC	ICT	Failure
Digital Audio Tape	Electronic devices	Failure
Direct Line	Banking and insurance	Success
Dive Restaurant	Entertainment	Failure
Dreamcast	Gaming & toys	Failure
DuPont's Corfam	Apparel & footwear	Failure
Earring Magic Ken	Gaming & toys	Failure
EFS - Corporate Foreign Exchange	Banking and insurance	Success
Evilla Sony	ICT	Failure
Facebook	ICT	Success
Federal Express' Zap Mail	ICT	Failure
Ford Edsel	Automotive	Failure
Ford Model T	Automotive	Success
Formule 1	Hospitality	Success

Geox	Apparel & footwear	Success
Gerber Singles	Food & Beverages	Failure
Herman Miller Aeron Chair	Furniture and home products	Success
Home Depot	Retailing	Success
Hubspot	ICT	Success
IBM PC jr	ICT	Failure
IKEA	Retailing	Success
Intuit Quicken ™	ICT	Success
iTunes	ICT	Success
JCDecaux	Advertising	Success
Joint Strike Fighter F-35	Public services and defense	Success
Kellog's Cereal Mates	Food & Beverages	Failure
La Femme	Automotive	Failure
Lynx barber shop	Beauty care	Failure
Maxwell House ready-to-drink coffee	Food & Beverages	Failure
Mc Donalds' Arch Deluxe	Food & Beverages	Failure
Microsoft BOB	ICT	Failure
Motorola Iridium	ICT	Failure
NetJets	Airfares	Success
New Coke	Food & Beverages	Failure
Nintendo Virtual Boy	Gaming & toys	Failure
Nintendo WII	Gaming & toys	Success
Nokia N-Gage	ICT	Failure
Novo Nordisk Novopen®	Healthcare	Success
OK Soda	Food & Beverages	Failure
OS/2	ICT	Failure
Outlet Villages	Retailing	Success
Pepsi AM	Food & Beverages	Failure
Pepsi Crystal	Food & Beverages	Failure
Pfizer Viagra	Healthcare	Success
Philips Alto bulb	Electronic devices	Success
Philips CD-i	ICT	Failure
Pink Taxi	Public services and defense	Success
Planet Hollywood	Entertainment	Failure
Polaroid Polavision	Electronic devices	Failure
Polo Ralph Lauren	Apparel & footwear	Success

QB House barbershops	Beauty care	Success
Quadraphonic Sound	Electronic devices	Failure
Rasna Limited's Oranjolt	Food & Beverages	Failure
RedBull	Food & Beverages	Success
RIM's Blackberry	ICT	Success
RJ Reynolds Premier smokeless cigarettes	Personal objects	Failure
SAP R/2	ICT	Success
Sony Betamax	Electronic devices	Failure
Sony Minidisc	Electronic devices	Failure
Sony Walkman	Electronic devices	Success
Sony’s Godzilla	Entertainment	Failure
Southwest Airlines	Airfares	Success
Swatch	Personal objects	Success
Telecom Italia FIDO	ICT	Failure
The Hot Wheels/Barbie computer	ICT	Failure
Thirsty Cat! and Thirsty Dog!	Pets	Failure
Toyota Prius	Automotive	Success
Unilever Persil Power	Furniture and home products	Failure
Virgin Atlantic	Airfares	Success
Voice Pod	ICT	Failure
Youtube	ICT	Success

Table 3.2: kinds of transformations observed by radical innovations

Kind of transformation	**Abstract description of the transformation**	**Example**	**Explanation of the example**
UF/create	A new direct benefit for the customer has been introduced		Modern mobiles integrate cameras for making photos
HF/create	An undesired effect of drawback, previously not considered in the reference industry, has been firstly		The shown wallet introduces means against robbing

	treated as a new competing factor		
RES/create	The consumption of an employed resource, previously not considered in the reference industry, has been firstly treated as a new competing factor		Mobiles with self-repairing screens require no maintenance, nor spare parts
UF/raise	A direct benefit for the customer has been substantially increased		DVDs have much more memory than CDs
HF/raise	An undesired effect or drawback results substantially decreased		Toothbrushes with replaceable heads are substantially more environmental friendly
RES/raise	The consumption of an employed resource results substantially decreased		*Concorde* was much faster than other planes
UF/reduce	A direct benefit for the customer has been substantially decreased		*Smart* has much less room inside than other cars
HF/reduce	An undesired effect or drawback results substantially increased		Disposable cutlery is much less environmental friendly
RES/reduce	The consumption of an employed resource results substantially increased		Limousines require much more room for parking

UF/eliminate	A direct benefit for the customer is not provided anymore		Taxis for women are not accessible by all the people, like other public means
HF/eliminate	An undesired effect or drawback, previously considered in the reference industry, results neglected and it is not treated anymore as a competing factor		Safety cameras imply unprecedented privacy issues
RES/eliminate	The consumption of an employed resource, previously considered in the reference industry, results neglected and it is not treated anymore as a competing factor		Pay per View TVs are not broadcasted for free like other channels

The occurrences of the above categories of modifications have been counted for each of the innovations listed in Table 3.1. The data have been subsequently exploited in [3.45] (constituting an integral part of the thesis), so to relate the probability of success with the diffusion of the kinds of transformations. It resulted therefore possible to establish the success probability of any radical innovation, in terms of the transformations taking place with respect to previous industrial standard. The formula arising from a logistic regression is reported in [3.45, §3.3.1]. Said equation is then employed to determine the *appreciation level* of radical innovations, as in [3.1 §3.2; 3.2 §3.3].

This stratagem allows thus comparing the goodness of new product ideas regardless their degree of innovativeness. The *appreciation level* stands consequently as a preliminary coefficient to guide decisions about product development alternatives. The usability of said indicator has been experimented in [3.1 §4] through a case study analyzing four innovative make-up lipsticks. The outcomes of the test show a good alignment between *appreciation level* values and the preferences expressed by a set of potential customers, but the decision criterion does not seem to identify the most beneficial business opportunity.

3.3 Innovation cycles and decision making

As anticipated at the beginning of the present Section, the capability of innovations to attract customers does not depend just on their superiority in terms of user value. It has been highlighted how the evolution of product architectures follows quite regular patterns with respect to the degree of observed innovativeness. Such an issue represents a trigger of the dynamic phenomena impacting product development initiatives [3.2 §2]. According to this understanding, *appreciation level* indicators would be capable to estimate the competitive advantage of product ideas in (hypothetical) static circumstances or in periods characterized by an equal opportunity of developing incremental or radical innovations. The contribution [3.46], constituting an integral part of the present work, outlines a background of the academic discussion about innovation trajectories and how they can impact choices in decision making. It is hereby remarked how the predominant qualitative nature of models describing innovation cycles has hindered the exploitation of the underlying notions within choices to be undertaken during design activities.

By taking into account the above considerations, the candidate has scrutinized the available innovation cycles and individuated the model which can be best employed for a quantitative determination of the suitability of incremental vs. radical innovations. The selected schema swivels on the fluctuations of the number of patents regarding the product under development, which is approximated to a parabola opening downward [3.47]. The choice of the reference model has allowed defining a coefficient, namely *pertinence*, through which to assess the capability of moderate and drastic redesigns to thrive in the marketplace, regardless their capability to generate customer satisfaction [3.2 §3.1].

3.4 The final proposal for selecting alternative product ideas

Decisions about the most beneficial product ideas can be then made by using two different indexes:

- *appreciation level*, as a proxy of the quality of the idea in terms of the value delivered to customers and the consequent success chances;
- *pertinence*, symbolizing the appropriateness of proposing and marketing radical or incremental innovations.

In order to ease the selection task, it is hereby proposed to consider a unique coefficient, named *advantage*, which assigns an equal contribution to the two mentioned variables [3.2 §3.4].

An experiment in the footwear industry has regarded the use of *advantage* as a means to tackle decisions about the product alternatives to be developed [3.2 §4]. A set of four perspective innovations concerning ballet pumps and tennis shoes has been analyzed in order to determine the matching *advantage* indexes for all the product ideas. The same alternatives have been evaluated by a sample of potential customers in order to achieve a first feedback about the liking of the proposed innovation. It resulted that the preferences of customers clearly match with *advantage* values. Such a test resulted as a preliminary positive verification of the overall decision support tool. The limitations about the rigor and the applicability of the method are clearly explained in [3.2 §5].

3.5 Open issues to be treated in the future research

The presented technique for selecting design alternatives emerging from the product planning phase has been successfully developed and verified. Likewise, the purpose has been reached of integrating measures for taking into account the effects of innovation cycles. The employment of a quantitative term describing the appropriateness of radical or incremental innovation when developing new products has consistently improved decision-making capabilities. The test with a basic version of the tool, considering just the capability of innovations to achieve superior customer value, has resulted in just partially satisfactory results [3.1 §4]. Conversely, the application of the complete methodology has given rise to a very good interpretation of customer preferences [3.2 §4.6].

The positive verification represents besides a trigger for fine-tuning the decision support tool, which blends drivers of relentlessly inexact models. In this sense, it is worth mentioning the arguments concerning the employment of Kano model (see Subsection 3.1.1), the approximations regarding the estimation of success [3.45 §5] or the shape of the curves depicting the quantity of patents (as highlighted in Subsection 3.3), uncertainties pertaining to the strategies to retrieve the most suitable set of patents [3.2 §5], any other measure undertaken to build the instrument (e.g. what is claimed in Subsection 3.4 with respect to the weights of the coefficients). All these aspects limiting the systematic level of the proposal represent cues for making the selection of product ideas more structured, reliable and especially even less biased by subjectivity.

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4 Conclusions and final remarks

The preface of the thesis has introduced the envisioned trend of engineering design towards embracing the concepts traditionally belonging to other disciplines. More specifically, it has been remarked how this phenomenon should mostly regard the scientific areas treating the role of human needs and expectations. The deficiencies of design methodologies have been analyzed and attempts have been consequently made to carry out improvements keeping the focus on the rebounds of engineering activities on individuals' life.

In this sense, proposals for process innovation put less emphasis on the practices to be implemented for obtaining savings. Contextually, design methods and decision supports for product development initiatives swivel on evidences concerning usefulness, customer satisfaction, superior value and experience. In order to perform the tasks, the thesis has exploited many insights provided by other scholars from different disciplines, such as engineering management, computer science, business, statistics, marketing and technology forecasting. However, the objectives of the work have necessitated experiments in order to extract findings and readings otherwise not available. For instance, the lack of tools to predict the success of radical innovations with respect to design features has implied the analysis of dozens of experiences in order to get evidences.

With these premises, the presented work has advanced tools to analyze industrial processes and their deliverables, to promote substantial innovations based on the proposition of new value, to support the selection of alternatives during the fuzzy front end of product development initiatives. The above methods, sharing notions, criteria and taxonomies, can be used in an integrated form or as stand-alone techniques. The text and the attached publications, submitted to be evaluated by the scientific community, make any effort to clarify when the tools are worth being used, which circumstances have to be met, which kind of information is required.

Undoubtedly, as a consequence of the vast ultimate goal of the research, what is proposed cannot be considered exhaustive or in its definitive form. Methodological lacks are highlighted for each proposed approach, technique or formula, as well as further objectives to be fulfilled are outlined. At the same time, many of the proposed models require further verifications. The progress of validation activities depended on several factors, comprising the time of fine-tuning the methods in their current form, the presence of literature evidences to compare the results with, the availability of industrial organizations or other subjects to employ the proposed tools or to answer surveys and questionnaires. In this sense, any scholar or practitioner willing to test the toolkit (or any of its parts) is welcomed and can contact the candidate to receive all the asked details or even ad-hoc computer applications easing the execution of experiments.

Eventually, despite the discrepancies between the levels of achievement of different methodological objectives, the candidate claims that the contents of the thesis can provide a valuable reference for a wide sample of industrial activities, otherwise poorly supported. If this belief resulted wrong, the presented design methods should be redesigned rather than abandoned, since the need of favoring innovation activities in industry is however pushing.

Publications and submitted papers constituting an integral part of the thesis

The attached contributions, authored by the candidate in the period 2011-2013, take part of the contents of the thesis and are thus included to provide a major understanding about the specific areas of the research and the overall methodological proposal. The sequence of the manuscripts is the following:

1. Rotini, F., Borgianni, Y., & Cascini, G., Re-engineering of Products and Processes: How to Achieve Global Success in the Changing Marketplace. Springer, 2012. Previously referred as [1.206; 2.1].
2. Borgianni, Y., Cascini, G., & Rotini, F. (2013). Business Process Reengineering driven by customer value: a support for undertaking decisions under uncertainty conditions. Submitted to Computers in Industry. Previously referred as [1.230; 2.10].
3. Borgianni, Y., Cascini, G., & Rotini, F. (2012). Investigating the patterns of value-oriented innovations in blue ocean strategy. International Journal of Innovation Science, 4(3), 123-142. Previously referred as [1.217; 2.11].
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8. Borgianni, Y., & Rotini, F. (2013). Predicting the competitive advantage of design projects to dynamically support decisions in product development. Submitted to the Special Issue on "Dynamic Design Requirement Management for Complex Product Development" for the International Journal of Product Development. Previously referred as [1.240; 3.2].

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Re-engineering of Products and Processes

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Preface

An abundant amount of literature regards the twenty first century as the innovation era, where shared knowledge fosters the progress with a strong impact at the economic and social levels. As a consequence, the capability to innovate will play a growing role in the destiny of companies. In the transition between quality-oriented and innovation-driven competition, considerable difficulties are faced by those firms, whose management mindsets have not assumed knowledge and innovation as a central asset of industries. With reference to such problems much academic research has been carried out in order to deal with continuous innovation programs, but the proposed indications have not resulted yet sufficient to master the competition, avoiding waste of resources and wrong decisions.

The debate about innovation and especially the factors that determine the success of innovation initiatives is rich and thought provoking. Scholars from different domains, especially business management, engineering, and computer science have disputed about the priority of the measures to be attained to achieve effective innovation tasks. Several models and strategies are grounded in concrete evidences from successful experiences. Is any proposed model capable to describe and justify any kind of successful innovation initiative? The authors' answer is "no" and we are convinced to share this opinion with the wide majority of industrial experts, researchers and readers. We believe that no tool has been developed to support the whole innovation cycle and to cover any aspect (strategic, technical, managerial, etc.) regarding industrial approaches to innovation.

Undoubtedly, this book cannot fill the gap. The issues that are treated to infer the motivations of the work are surely not exhaustive in the panorama of innovation strategies. Much academic research and industrial practice is still needed to build rigorous models and efficient tools. However, we are convinced that such a manuscript and the presented techniques can result in a useful support to industries facing the need to undertake decisions about the renovation of processes and products and a valuable contribution to researchers and PhD students who are interested in the field.

The whole coverage of this book swivels on a basic assumption, that results unopposed in the literature and that we have considered as a fundament for the book: the capability to provide customer value is a primary driver in achieving business success. According to our studies and background, such hypothesis can be deemed valid in both static and turbulent stages that characterize the paths of evolution encountered by goods and services. If the focus on value contributes to sustain successful business, all innovation initiatives, being addressed at products or processes and providing radical or marginal changes, cannot overlook their potential impact on customer satisfaction. In such a perspective, the combined set of presented value-oriented methodologies, namely Integrated Product and Process Reengineering (IPPR), constitute the core of a toolkit for the identification of the most favorable directions within innovation initiatives. IPPR represents a system to support crucial decisions in the industry, capable to orientate choices among a set of plausible reengineering activities, according to value criteria. The methods that we illustrate in the present publication deal with different specific objectives and conditions encountered along industrial production, research, and planning. Actually, three recurring situations are taken into account, that typically take place along product lifecycle: the birth of new products and the organization of suitable processes, their maturity often accompanied by lacks of competitiveness, the need to drastically rethink the outputs that are offered to customers.

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Contents

Chapter 1
Introduction

1.1 Generalities of the Reengineering Strategies

By treating the problems related to products and processes, thus the outputs of industrial activities and the ways to achieve them, a large range of business, technical and organizational features have to be taken into account.

The present Chapter first overviews general and comprehensive models that attempt to deal with a large range of the recalled aspects and provides the relevant definitions for the main concepts encountered in the book. According to this aim, this Section illustrates the main notions concerning Business Process Reengineering (BPR) and New Product Development (NPD), in order to facilitate the reading and understanding of the investigated topics. The field of BPR includes a broad set of techniques to approach the task of improving the internal processes, by optimizing the allocation of resources, the employment of skills, the performances of the end products, etc. Conversely, NPD groups the most common practices undertaken to innovate products and services.

Section 1.2 is dedicated to point out the product lifecycle phases that are addressed and supported by the instruments described in the book. A more detailed review of the subjects of interest is presented in Sect. 1.3, that eventually points out the main identified deficiencies and open issues with reference to the surveyed methodologies and models. Finally, Sect. 1.4 clarifies the purpose of the book, addressing the general goals and the methodological objectives to be attained by building a versatile system to support decisions in troublesome industrial contexts.

1.1.1 Redesigning Business Processes

The concept of "*business process*" was born in the early 1990s as a means to identify all the activities that a company performs in order to deliver products or services to their customers. The need of describing and formalizing the actions

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performed to turn resources into benefits for the customer was strongly perceived in those years since companies started worldwide to radically reorganize their activities in the attempt to regain the competitiveness lost during the previous decade. The "business process" concept has been defined by several authors in the literature with the aim of providing a reference for modelling and analysis tasks.

Davenport [1] stated that it is "*a structured, measured set of activities designed to produce a specific output for a particular customer or market. It implies a strong emphasis on how work is done within an organization, in contrast to a product focus's emphasis on what. A process is thus a specific ordering of work activities across time and space, with a beginning and an end, and clearly defined inputs and outputs…. Processes are the structure by which an organization does what is necessary to produce value for its customers*". Thus, according to Davenport, a business process is identified through clear boundaries, inputs, outputs and activities ordered in time and space: the purpose of the process is the transformation of inputs into outcomes having value for the customer.

Hammer and Champy [2] give a more general definition focused on the process outcomes according to the customer perspective: "*a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer*".

Eventually Johansson et al. [3] emphasizes on the creation of links and interrelations among the activities and on the transformation that takes place within the process, highlighting the value chain concept: "*a set of linked activities that take an input and transform it to create an output. Ideally, the transformation that occurs in the process should add value to the input and create an output that is more useful and effective to the recipient either upstream or downstream*".

Plenty of definitions have been proposed, but in essence all have the same meaning: business processes are basically relationships between inputs and outputs, where inputs are transformed into outputs throughout a series of activities, which add value to the inputs.

According to the cited contributions, a business process should be therefore characterized by (Fig. 1.1):

- clearly defined boundaries, inputs and outputs;
- activities ordered in time and space;
- a clearly identified beneficiary of the process outcomes, e.g. the customer or any stakeholder;
- the transformation taking place within the process that is meant to add value to the inputs;
- an organizational structure;
- one or more functions to be performed.

Such properties suggest that the business process can be considered as a technical system able to generate value by manufacturing products or delivering services under certain boundary conditions such as market demand, raw material availability, product requirements, technology and know-how resources, etc. When the process is not able to exploit the available resources according to their

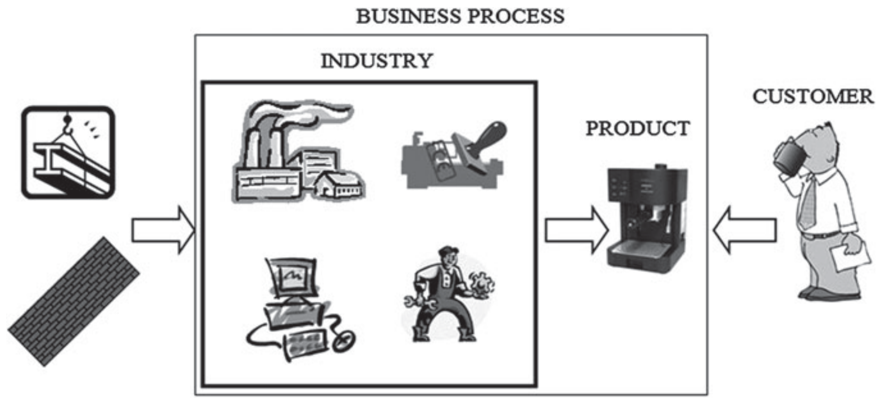

Fig. 1.1 Elements constituting a business process

potentialities, its capability to survive market competition decreases dramatically, due to a disadvantageous balance between the provided benefits and the involved costs. Thus any organization has to pursue continuous business improvements through planned evolutionary paths in order to preserve its competitiveness; this evolution can involve the business at different levels and it requires resources of knowledge dispersed across different fields and disciplines.

During the last twenty years, many methods have been suggested to address the redesigning and innovation of business processes. In the management field, but also in the scientific literature, such reorganization tasks were grouped under the name of Business Process Reengineering (BPR) activities. Several definitions of BPR are available but one of the most acknowledged is that provided by Hammer and Champy [2], who depict it as "*the fundamental rethinking and radical redesign of a business process to achieve dramatic improvements in critical contemporary measures of performance, such as cost, quality, service, and speed*".

In line with the above definition, IPPR provides appropriate hints to direct the process reengineering efforts towards solutions that comply with products quality, customer satisfaction, resources savings and suitable sequences of phases to achieve such issues.

1.1.2 Rethinking Products and Business Models

In particular circumstances, it is required to radically redefine the outputs of the business process, rather than to rethink the ways to generate them; as a result, the core of the innovation task shifts towards redesigning, manufacturing and delivering new products. In this context, NPD cycles are typically concerned as conjoint activities involving business, marketing and technical expertise within companies. The continuous information exchange among the various units of the firm debates about the feasibility of new products, the knowledge required during the development stage, programs for resources allocation, the financial sustainability of the project, the target group of expected users, the foreseen response from the customer arena, the commercial strategy, etc.

Besides, it is acknowledged how the destiny of NPD initiatives is mainly determined during the Fuzzy Front End of the design cycle, i.e. the initial phases, when the design process appoints the fundamental aspects of the new goods [4–6]. In such segment of the development task the human needs to be satisfied are crucially individuated and represent the main trigger for exploiting business opportunities. Clearly identified customer requirements are regarded as the inputs for the conceptual design, whereas product specifications are defined and eventually conflicting demands are faced throughout problem solving tools. The NPD cycle is therefore grounded on the set of requirements to be fulfilled, which in turn provide value for the target customers. The beginning of the development process captures plenty of the characteristics related to the final commercial offer, ranging from the identity of the company which strives to address unspoken needs to technical performances to be achieved in order to cope with established exigencies. In this sense the NPD task commences by giving prominence to the ways to manifest the culture of the company, the position it is ought to be gained in the marketplace, novel paths intended to deliver value to customers and thus, altogether, what we can identify with the concept of "*business model*".

From a historical perspective, the wide diffusion of the "business model" term is consistent with the growing role played by Internet and particularly by the e-commerce in marketing activities. By the 1990s of the previous century, the adoption of web retailing was considered as a sort of mantra for determining companies' fortune. Despite such enthusiasm, numerous e-commerce experiences resulted in tremendous flops, as surveyed by Mahajan, Srinivasan and Wind [7], because of their lack of strategy within flawed business models [8]. As a consequence, the notion of business model started to assume a wider meaning and to identify patterns of value creation by exploiting business opportunities [9]. On the same wavelength Chesbrough and Rosenbloom [10] individuate the primary objective of the business model in the proposition of the value necessary to provide commercial interest to technological advances. In more general terms Francis and Bessant [11] address the objectives of *business model innovation* in the "*reframing of the current product/service*", thus allowing to individuate "new challenges and opportunities". In order to fulfil the task, Johnson et al. [12] depict Customer Value Proposition as the first step in the creation of an alternative business model with the aim of fulfilling unsatisfied needs.

The efforts to redesign business models, and consequently NPD tasks, are therefore associated with value innovation initiatives. Value innovation is acknowledged, also within studies about entrepreneurship, as a fundamental strategy to obtain competitive advantage by proposing value profiles that deviate from previous industry standards. The renewal of business models is intended as a means to achieve differentiation from competitors in ways valued by market [13, 14], assuming distinguishing features with respect to any other sort of disruptive innovations [15]. Indeed, such kind of innovations fundamentally redefines the market boundaries through New Value Proposition (NVP) initiatives that emphasize on previously overlooked product or service attributes, which result valuable for the customers. In this perspective Gotzsch, Channaron and Birchall [16] emphasize the value provided by communicative capabilities of products, especially when the main features, e.g. performance and price, have reached their maturity.

In order to clarify the meaning of the introduced terminology, within the present book we depict a *value profile* (or *value curve*, with the reference to the graphical model introduced by Kim and Mauborgne [17]) as a *bundle of properties and features, characterized by their performance or offering level, belonging to a product (or service), which generate benefits for the user*. Such features are indicated throughout the text with attributes (as observed through the lenses of end users) or customer requirements (from the viewpoint of the enterprise), whereas the *product* they belong to, is intended as *the output of the business process, thus a set of tangible items and matched delivered services*. Moreover we exploit the definition provided by Barnes, Blake and Pinder [18] who identify a value proposition as "*a clear, compelling and credible expression of the experience that a customer will receive from a supplier's measurably value-creating offering*". As a result NVP pursues the objective of differentiating value profiles from those existing in the industry, with the attempt of developing new generations of products and services that enhance customer satisfaction by offering in a synergic way additional benefits and unprecedented experiences.

1.2 Classes of Reengineering Problems

Facing innovation issues, companies typically have to pursue the double goal of delivering customer satisfaction and carrying out industrial processes with a limited amount of expenditures and consumed resources. This implies that the development of products and processes involves tangled interrelations between companies policies and the features affecting the market and the customer perception.

In a simplified vision, as already advanced by Miles' Value Engineering [19], the firms have to maximize the ratio between the profitability of the delivered products and services and the costs pertaining the business process. By considering the profitability directly related with customer satisfaction, quality oriented tools have been developed to increase the numerator of the ratio. A wide diffusion in the industry regards the *Quality Function Deployment* [20], a mathematical model to maximize customer satisfaction by individuating the most advantageous combination of product attributes performance within the range of feasible technical solutions. On the other hand, the most diffused BPR strategies are aimed at shrinking the production costs (thus minimizing the denominator), by eliminating all the superfluous expenditures and thus obtaining lean processes. In such framework, most of the work has been dedicated to optimize the terms of the fraction (benefits and costs), rather than the ratio as a whole. Within the landscape of reengineering techniques, the

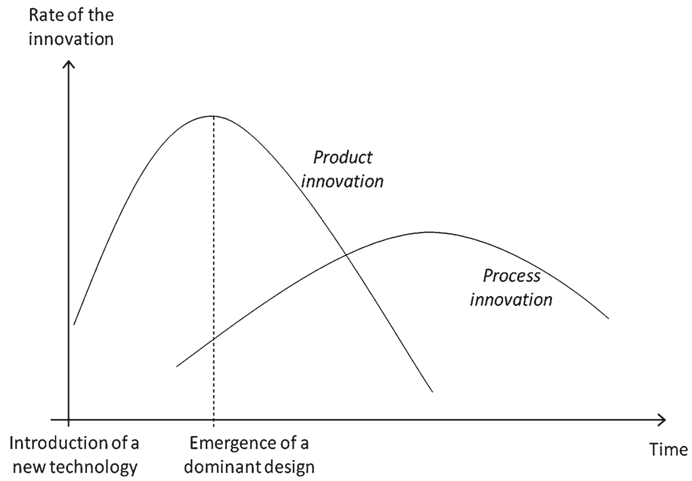

Fig. 1.2 Innovation timing according to the dominant design model

present book provides a contribution in terms of their capability of taking into account the aspects related to both processes and their outputs.

However, the various tools introduced through IPPR are consistently either process-oriented or product value-driven. The choice is dictated by the evolution of industrial products, which alternates the predominant relevance of performances and costs. Well-established models, such as the one developed by Utterback and Abernathy [21] highlight, as depicted in Fig. 1.2, that the focus of industrial efforts shifts along systems lifecycle from product characteristics to processes (and vice versa): more specifically the breakpoints are represented by the emergence of a dominant design and the introduction of new technologies. Thus, firms should prioritize their reengineering endeavours according to product development stages and market conditions. On the basis of such evidences three different classes of industrial problems are outlined and described as follows. As a result of sustained innovation, it is likely that the tools introduced to support the classes of problems are to be used in a cyclical fashion, e.g. the definition of new product features determines the need to reconsider the value impact of the phases belonging to a prototypal industrial process.

1.2.1 Class of Problems #1: Organize a New Process to Overcome Market Boundaries

According to Pahl and Beitz [22], the need to develop new products or services arises from different stimuli which may be internal or external to an organization. They can be summarized as follows:

- the market: new customer needs to be fulfilled, new functionalities to be delivered, etc.;
- the company: new ideas and results coming from research and development activities, availability of new manufacturing technologies, etc.;
- other: new policies, environmental issues, etc.

Typically such stimuli represent great potential inputs for individuating new business opportunities, as described more in detail in Sect. 1.2.3.

However, the exploitation of the previously individuated stimuli may result in the inadequacy of the know-how, the technologies or the managerial skills belonging to the firm in terms of delivering the new elements of value. Consequently, novel product ideas often encounter significant problems to access the market due to a large amount of factors such as design or manufacturing costs [23], organizational issues [24], required technologies or materials [25], relevant drawbacks [26], resources consumption [27].

In other circumstances, changes in the boundary conditions, such as shortage of materials or semifinished products, consistent modifications occurred along the supply chain, rise of costs, come out as relevant hindrances to business.

In all the above described conditions, the necessity emerges to basically rethink the business process, due to the insufficient generation of value or profit drops.

Preliminary hypotheses about how to overcome the mentioned under capacities may result in unsatisfactory processes and/or limited performances. The tools developed within IPPR to address such kind of problems are aimed at evaluating which phases and activities require major adjustments in order to align the business process to the expected delivery of value.

1.2.2 Class of Problems #2: Individuate the Bottlenecks that Generate the Loss of Competitiveness

Also after their launch, all the products have to pursue continuous improvements in order to satisfy changing customer requirements or market conditions. This task implies an evolution of production and business processes at different levels. In some circumstances minor reorganizations in the design or production phases can be sufficient to fulfil the evolving demands; besides, these actions usually bring only to limited improvements, mainly focused on preserving the appeal of the product in the marketplace. In other market circumstances, as in event of declining competitiveness, the companies have to develop more remarkable innovations.

In order to envisage an enhanced business process addressed at gaining competitiveness, the current sequence of industrial activities can be analyzed to highlight strengths and weaknesses. Thus, investigating the process with a focus on the value provided to the end user means analyzing the contribution of each phase to the generation of product/service attributes. Such task has to take into account the impact of the phases in determining the customer satisfaction, considering as well the involved resources in delivering such contribution. As a result of the analysis, it may happen that one or more phases of the process provide a marginal contribution, show poor performances or their fulfilment determines an excessive consumption of resources. On these bases, the main value bottlenecks are individuated and the suitable reorganization actions can be prioritized to overcome the emerging deficiencies. Subsequently, the process can be reengineered by identifying the proper technical solutions that implement the individuated actions.

1.2.3 Class of Problems #3: Build the Value Profiles of Innovative Products

When facing a NPD task, the common approach is to reach a trade-off among the established and new (if any) parameters or features that characterize the redesigned system. Such reengineering mode follows a cautious logic of business transformation and typically brings to minor improvements, disregarding the early intentions and missing to exploit the initial ideas. Although a not marginal school of thought encourages companies in preserving to compete with their established business models by delivering incremental improvements, a growing amount of researchers supports the need to perform more radical innovations, as in [28]. To this end, a process-oriented approach is not capable to effectively address reengineering activities focused on radical product innovation. The need to carry out more disruptive innovations takes place especially when established technologies get superseded or customers start to attribute value to novel product features.

With reference to the first case, according to a well-established model, the main performance of a system grows by typically following a S-shaped curve [29] as a function of the research effort that has been dedicated to its development. When the system has reached its maturity stage, its evolution approximates a limit with hardly appreciable improvements. In this phase, the industry gradually adopts emerging new technologies, which are capable to overcome the previous performance limits of the system. The phenomenon is graphically depicted, as shown in Fig. 1.3, through the birth of a novel S-curve, which gradually grows, hence surpasses the old performances standing still and supersedes the preceding technology. Such representation is commonly employed to illustrate long periods of incremental development of the systems and turbulent phases characterized by technological ferment and thus radical innovation.

Besides the “natural” pattern of growth, the shift to technologies with higher performances can be dictated by external factors. Typically, remarkable discontinuities in customer demands and preferences lead to the need to perform technological advances, implying to acquire wider knowledge to stay ahead in the competition.

In the cases regarded as radical innovations driven by value issues, the innovation process has to fulfil needs previously unsatisfied within a given industry. Considerable advantages can arise by investigating further aspects of value that consumers might care about, such as way of using, overlooked technical or emotional features, resources committed to the user, maintenance, environmental

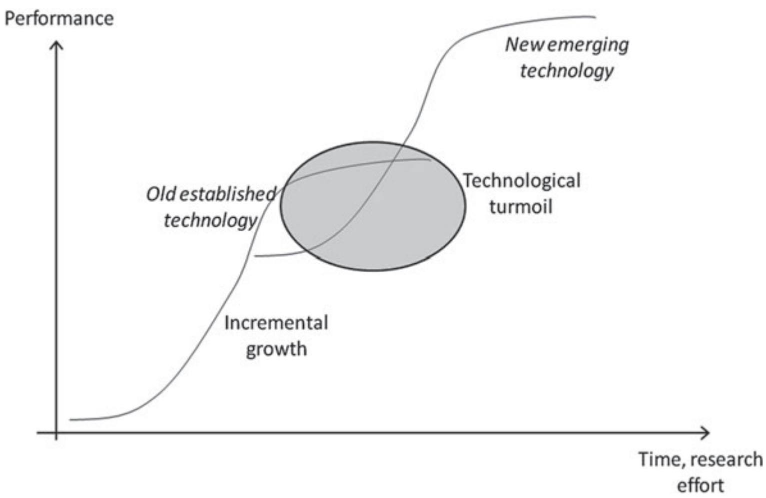

Fig. 1.3 S-curve model of technological substitution

impact, customer care, end of product lifecycle. Additional attractive features can be thus attributed to the current product profile with the aim of boosting customer satisfaction. The focus on customers and on their perception of products and services has gained an increasing role within companies, by affecting industrial practices, policies and product development cycles, leading moreover to a great impact on the required managerial skills.

In each case a difficult task is yet represented by the implementation of suitable technical and organizational solutions which should allow to perform the manufacturing and the marketing of radical innovations. Such phase is commonly characterized by the emergence of conflicting requirements and the involvement of knowledge dispersed across many disciplines. Given the great consequences of the success or the failure resulting of such an overwhelming design effort, suitable supports for directing radical innovation processes would result considerably valuable.

According to Christensen's studies [30, 31], the first mover advantage is particularly relevant when the introduced products are characterized by additional features, rather than new technologies. On the same wavelength, as already remarked in Sect. 1.2, a thread of business literature emphasizes how value differentiation can result in profitable innovation experiences. Given the consistent advantages attainable through NVP strategies, useful tools have been developed within IPPR to support companies in performing this sort of initiatives.

1.3 Brief Review of Tools and Methods Available in Literature

As already recalled, industries face the challenge of suitably and continuously improving their offer in terms of marketed products and delivered services, as required by rapid changing and highly competitive marketplaces. In order to fulfil the new expectations of customers and stakeholders, innovation and reengineering efforts have to be oriented towards industrial business processes and distributed products.

1.3.1 Process Reengineering

The literature witnesses considerable advantages arisen by BPR initiatives and describes textbook success stories. Conversely, plenty of contributions from different periods point out a high percentage of unsatisfactory results concerning BPR practical implementations, causing therefore diffused scepticism in the field. In the 1990s of the previous century, Holland and Kumar [32] estimated in a range between 60 and 80% the share of BPR experiences which have not pursued the expected out-comes. More recently, a review of the success rates of BPR initiatives has substantially confirmed those percentages [33].

Beyond the excessive expectations placed by managers and CEOs, the reasons of diffused BPR flops can be related, according to literature, to three main motivations: the diffused disregard of the appeal of process outputs, the complexity of industrial systems to be administered, associated with uncertainty issues, and the defiance of people in the organization.

1.3.1.1 BPR Deficiencies in Focusing on Success Determinants

BPR strategies strive to take into account a wide range of features relevant to the industries, such as price, lead-time, delivery conformance, performance, quality and reliability, sources of risk, environmental factors and life-cycle costs. Nevertheless, most of the developed approaches have been characterized by the priorities assigned to one or more of the previously listed features, meant as the main triggers to successfully perform the product and process development [34, 35]. Furthermore, under the aegis of BPR, countless projects have been carried out to promote the introduction of Information and Communication Technologies (ICT) [36] and most of them reflected the intended aim of shifting towards Lean Manufacturing practices [37].

Herron and Braiden [38] have developed a methodology to assist the user in identifying the most appropriate lean manufacturing tools and techniques to address the problems of a particular company through a quantitative compatibility assessment. The results confirm that lean manufacturing tools may have a major impact only on specific areas of the business, but they are not a panacea for any kind of problems. Typically, companies experienced problems in areas such as under capacities, scheduling and innovation in products and processes, which represent issues that are not directly influenced by lean manufacturing methods.

In such framework, failures of BPR initiatives can be explained by strategies oriented on redesigning just the features pertaining the internal processes [39] and focused mainly on resources savings [40]. A great quantity of experiences, with the objective of achieving lean processes by mimicking past experiences, have frequently underestimated the relevance of the value delivered to customers [41], seen as a determinant for the success of BPR initiatives [42]. The BPR goal of building and organizing a business architecture aligned to fulfil customer demands, as depicted by Edwards and Peppard [43], has thus often been disregarded.

From this point of view, other methodologies have been proposed in order to batten down the hatches, by proposing approaches that take into account additional objectives than costs lowering.

A not negligible amount of works approaches the problem of dealing with concurrent issues in terms of costs management and product requirements; an example is [44], where the integration of Value Engineering and Target-costing techniques is proposed to support the product development process in an automotive company. Such a methodology was applied to a case study aimed at improving costs and performances of a vehicle engine-starter system, according to customer and company needs. In [45], an integrated multidimensional process improvement methodology has been proposed to address the yield management, process control and cost management issues for a production process. Total Quality Management (TQM) is used to manage the cost of the system according to the quality requirements and a discrete event simulation is employed to achieve process reengineering and improvement. Another method has been presented in [46] based on a heuristic approach which supports the practitioners in developing a new improved business process starting from the current design. The method has been extrapolated from different successful and acknowledged best practices to carry out BPR tasks. These heuristics have been synthesized in a checklist for process redesigning with the objective of contemplating and harmonizing different management approaches: Total Cycle Time compression, Lean Enterprise and Constraints Management.

In the panorama of the techniques supporting business management, the Balanced Score Card (BSC) [47] represents the most established approach to identify reengineering directions on the basis of multiple criteria. Its main strength stands in combining financial and nonfinancial performance indicators in a coherent measurement system. The enterprise is evaluated according to indicators belonging to four different areas: the financial perspective; the customer satisfaction; the internal business process view based on the concept of the value chain; a final index taking into account the innovation and the learning perspective. The advocated deficiencies of the strategy regard BSC limitations as a result of invalid assumptions within the innovation economy [48]: its rigidity, its conception of knowledge and innovation as a routine process, its focus on the internal processes of the company determine biased evaluations since the relationships with the environment are neglected. Such limitations make the BSC performances poor in event of radical business modifications that frequently come out in the innovation age.

1.3.1.2 BPR as a Support for Decision Making and Decision Support Systems for BPR

From a methodological point of view, BPR applications represent complex multidisciplinary tasks, dealing with multiple sources of risk [49] and a wide range of facets regarding different fields of expertise [50]. On the same wavelength, Ozcelik [33] underlines how the major risks related to BPR implementation regard projects involving different functional units of the companies.

Furthermore, reengineering issues have to be directed towards complex systems, such as business and industrial processes, which have by nature not deterministic behaviours [51] and that require dynamic time-dependant models. As a consequence, the uncertainty regarding the model and the parameters governing the business process affects the outputs of BPR tasks, leading firms to take extremely risky decisions in order to pursue the planned enhancement strategy. It follows that the development of Decision Support Systems (DSSs) aimed at addressing the most appropriate directions for redesigning industrial processes represents a flourishing research field.

Like each decision-making activity, the redesign and planning of business processes is associated with uncertain inputs and risk. Lambert et al. [52] take into account relevant risky factors starting from the modelling phase by representing such additional information in IDEF frameworks.

Many research efforts about DSSs dealing with the uncertainty that characterizes a business process have been carried out; their complementary aims range from enhancing specific aspects of the industrial strategy, to supporting the development of certain categories of firms and increasing well identified performances. Min et al. [53] developed a decision support system suitable for banking industry, assessing appropriate Business Process Reengineering tasks under multicriteria analysis and present constraints. Williams et al. [54] deal with risk and uncertainties associated with BPR initiatives, focusing on organizational hurdles and providing guidelines for pursuing incremental or radical changes with reference to expected benefits and available investments. Wang and Lin [55] introduced genetic algorithms in order to efficiently schedule industrial processes for a make-to-order manufacturing firm. Their research and application is tailored for resource allocation decisions in an environment characterized by time pressure with regards to delivery dates. By exploiting simulation techniques Mahdavi [56] built a model meant to dynamically control the production activities of a flexible job-shop, whereas manufacturing processes are characterized by stochastic events.

Another branch of the research that involves intelligent decision making within industrial processes affected by uncertainty regards methods tailored for choosing the most favourable alternative among a set of already identified opportunities. Through the employment of simulation models addressed at treating uncertain inputs, Völkner and Werners [57] developed a decision-support system for choosing the best option among alternative business processes, approaching the problem with quantitative parameters. The developed tool is consistently tailored for those cases involving decisions about operations sequences. Gregoriades and Sutcliffe [58] proposed a decision-based system, taking into account industrial performance and human factors, capable to evaluate the advantages of introducing and managing a new candidate business process. The system simulates the business process and assesses further opportunities and risks, providing statistical outputs with reference to the generated scenarios.

Still with reference to BPR tasks, the problem of working with not deterministic and uncertain models is compounded by the presence of qualitative parameters. In such framework recent contributions introduce measurable parameters to deal with uncertainty issues within relevant aspects related to business processes, i.e. customer relationship [59] and purchasing management [60]. In order to compute even qualitative aspects, He et al. [61] have developed a Fuzzy Analytical Hierarchy Process to support the choice among different BPR alternatives.

Still within the development of tools to support decision making, Ramirez et al. [62] point out how business process redesign initiatives and conjoined IT advances positively affect product performances. Their research sheds light on the opportunities provided by process-oriented programs in order to achieve managerial success, regardless the implementation of novel IT supports. Therefore the analysis of industrial processes and its implications represents a relevant starting point for designing business advances.

1.3.1.3 Social Fallouts of BPR Experiences

Although our work tries to contextualize BPR in the field of engineering innovation, we cannot neglect the most frequent and harsh critique which gets directed towards most of these applications. The literature charges BPR about its strict focus on efficiency and technology and the disregard of people involved in the initiatives: not just customers and stakeholders, but also the labour. Very often the label BPR was used as a justification for major workforce shakeouts with the aim of decreasing organizational and production costs, instead of suggesting any kind of improvement based on process innovation. Knights and Wilmott [40] overview numerous contributions that demonstrate job losses (as supported by Grover [63]), complaints of workers subjected to BPR experiences, scarce consideration of labour welfare. Grint [64] goes as far as to talk about alienation amongst workforce. Additionally, whereas BPR applications have turned out as a misfortune for the employees, on the other hand the disregard of human factors have hindered the successful display of reengineering programs, thus resulting in complete disasters.

Management practices, such as those regarding human resources, do not fall within the objectives of the present book. However, it is useful to remark that a full understanding of successful reengineering projects advocates dealing with, among a wide range of factors concerning management disciplines [65], human factors and employment issues without making the innovation initiative a “blood, sweat and tears” experience for people.

1.3.2 *Product Reengineering*

As recalled in Sects. 1.1 and 1.2, several studies demonstrate how innovations in terms of the value directly perceived by the customers deliver the firms fundamental benefits in terms of market success. The literature includes contributions tailored to maximize the customer satisfaction and proposals intended to exploit unprecedented sources of value.

The methods of the first set (Sect. 1.3.2.1) are intended to design products whose mix of characteristics and performances ought to attain the greatest appeal of customers within the range of known technical solutions. Such techniques are consistently based on people opinions and preferences expressed through market researches, whereas the extracted data are used as inputs for optimization procedures. These approaches concentrate just on the explicit and revealed needs to be fulfilled, yet they usually do not bring to the identification of unexplored business opportunities or to disruptive innovations.

A particular set of tools belonging to the second group makes reference to the tendency of integrating manufactured products and a bundle of associated services (Sect. 1.3.2.2). Other methods are addressed at stimulating the generation of new business ideas swivelling on the fulfilment of different, diffusely latent, customer needs (Sect. 1.3.2.3). With reference to this kind of methodologies, the actions directed towards the fulfilment of superior value are mostly aimed at breaking quality/cost tradeoffs within the established competition in the reference industries, thus putting in practice tremendous differentiation strategies.

1.3.2.1 Innovations Based on the Optimization of Product Performances

In order to comprehensively pursue the fulfilment of the product requirements elicited by users, several methods have been developed in the consumer research field, with the objective of capturing the so called "Voice of Customer" (VOC); in [66] an extensive survey is presented. Many approaches such as those based on Free Elicitation, Laddering, Conjoint Analysis, etc., try to assess the product attributes having major interests for the user by interviewing techniques in which the customers are asked to identify the characteristics they consider relevant in the perception of a product. Other methodologies (i.e., Empathic Design, Information Acceleration, etc.) are based on observing the consumer behaviour during the day life. The assumption behind these approaches is that designers can easily identify opportunities for products in response to perceived needs, by examining the consumer behaviour. Without shedding light on novel and potentially valuable attributes, as claimed by Ulwick [67], asking the customers helps just to reveal the needs they are clearly aware, since they are capable to figure out only feasible solutions regarded of minor product improvements. Bower and Christensen [68] go as far as to claim that the inability of firms to efficiently innovate is caused by the aptitude in strictly meeting current customers expectations.

Along the product development process, once the main attributes of value have been established, the application of Quality Function Deployment (QFD) is widespread [69–71]. It is worthily employed in combination with the above cited survey methods aimed at clarifying and prioritizing the needs customers are aware of. QFD is used as a method to relate the customer demands to the engineering requirements in the early stage of New Product Development (NPD) in order to maximize the satisfaction of the end user. The task is carried out by introducing quantitative variables and Likert scales to characterize the extent of customer satisfaction, the technical performances and their interplay. The intertwining among the variables is represented through a suitable diagram, namely the House of Quality (HoQ).

Despite its deliberate domain of application, some approaches have been developed in order to use QFD for product planning tasks. In [72] QFD and Design Structure Matrix were used to assist the designers in understanding customer needs and planning the early stage of product conceptualization. A market-driven design system was proposed in [73] to integrate QFD technique with commercial analysis. As claimed in [69], the suggested approach allows to concentrate the design efforts on particular product features, with the intended scope of maximizing the expected market appraisal. More recently, Ulrich and Eppinger [74] illustrated a methodological approach for establishing the relative importance of emerging customer needs. Nevertheless such kind of contributions did not result capable to overcome the limitation of optimization methodologies in investigating a narrow space of product profiles with poorly creative results.

In order to describe with more rigour the determinants of customers perceived value, Kano et al. [75] developed a two-dimensional model that relates the degree of satisfaction provided by each attribute according to the offering level it is supplied. Kano introduced three categories for the customer requirements which effectively play a role within the delivery of satisfaction: must-be, one-dimensional and attractive. The most appropriate class of customer satisfaction is determined as a result of tailored VoC questionnaires. The non-linearity between the performance of the attributes and the ensuing satisfaction Kano model allows to highlight is exploited to suggest which characteristics are worth of investments at the maximum extent [76, 77].

The suggested classification is a powerful tool to perform the analysis of the impact played by product features and thus a suitable model to strengthen QFD optimization strategy [78, 79]. The appropriate exploitation of the qualitative information arising from the Kano model, more specifically the categories of customer satisfaction, does not jeopardize the benefits of QFD in treating quantitative variables. Due to indexes representing individual evaluations, the main problem is conversely related to the management of uncertainty. The extent of uncertainty further increases as additional inputs are introduced, leading consequently to marginally reliable outputs to support decision making.

By addressing such problems, Fung et al. [80] have surveyed QFD models to achieve the understanding of uncertainty introduction and propagation, revealing how the relationships between customer requirements and engineering characteristics play a major role. Further on, their research evaluates the effectiveness of linear programming models with fuzzy coefficients to estimate the functional relationships. The employment of fuzzy set theory represents the most diffused approach in the literature for managing the uncertainties and the dynamics of the inputs in QFD; Kahraman et al. [81] proposed a critical review of these applications, but more recent contributions are present. Experiences dealing with uncertainty carried out by means of fuzzy set theory regard also the Kano model [82], as well as its utilization in combination with QFD [83]. From this point of view, although regarded as effective procedures, such ways of managing uncertainty clash with the difficulties in employing fuzzy sets, due to mathematical complexity.

1.3.2.2 Innovations Based on the Delivery of Products and Matched Services

An effective way to map possible patterns of product development regards the investigation of the possible circumstances or phenomena that can impact the use or the behaviour of the artefact. Such monitoring involves all the possible stages of the product existence, from manufacturing to disposal, according to the concept of Life Cycle Engineering. Comprehensive observations of a rich bundle of factors influencing the behaviour of products and users have led towards the delivery of offers including both goods and matched services. The current tendency depicts the need of the companies to manage a greater extent of features and competing factors regarding what could be originally referable to both products and services. Successful business initiatives have offered customers new packages of value attributes by stressing the unique experience faced during the use of certain products. Diffusely, manufacturing firms have endorsed the strategic importance of delivering complementary services, resulting in dramatic business models rethinking [84].

In this framework, Service Product Engineering (SPE) [85] and Product Service Systems (PSSes) [86] have been developed with the aim of generating additional value for products. These methodologies address a growth strategy based on innovation in mature industries, typically by augmenting the overall value for the customer through increased servicing.

Hara et al. [87] developed the notion of Service Product Engineering (SPE) as a means to provide more value to the customer by offering not only products, but also the related services. In their approach, with a tailored VoC task, the designers collect the information about the customer individuality represented by elements of value which constitute the so called “Persona” model. Subsequently each personality is classified into separate groups that summarize the main traits of the customer inclination and internal state. At the same time the characteristics of different service product alternatives are classified through Kano model, heading to assess the impact they have on the receiver’s internal state. Eventually, this allows to evaluate the expected customer satisfaction on the basis of the aptitude of different groups. Although dealing with disparate kinds of attributes, such as product features and advantages due to matched services, the main limitation of

SPE approach reflects the inadequacy of VoC in individuating new sources of value than those already outlined.

In the last decade, great attention has been bestowed to PSSes, which represent a particular class of value proposition, that, eventually, can be jointly designed by the enterprise and its customers. The outcome of PSS application is a mix of tangible products and intangible services, which are developed in a synergic way in order to satisfy customer needs [88]. A particular objective of the methodology is represented by sustainability, which is pursued under the assumption that the combined development of product and services results in the reduction of materials consumption in a lifecycle perspective.

Up to date the literature witnesses however only few examples of complete PSSes tasks, due to the lack of a rigorous theory and application procedure [89]. As observed by Baines et al. [90], several contributions provide marginal developments of conventional design methodologies and lack the evaluation of the pursued achievements in practical applications. It follows that not all PSS experiences have fulfilled the expected goals in terms of sustainability and competitiveness, nor the trend of increasing servicing has resulted successful in Business to Customer (B2C) companies [88].

According to the authors' view, the experiences involving New Product/Service Development represent a valuable starting point for companies in renovating their offer, but cover just a niche of profitable initiatives about business model innovation.

1.3.2.3 Experiences of Innovation with NVP

Strategies aimed at performing radical innovation, as those regarding business models, are deemed to play a steadily increasing role within the development of new products [91]. Chesbrough [92] assesses how the innovation of the business model results a fundamental task for firms success, although difficult to be tackled. Kagermann [93] points out how the difficulties faced by many companies deal with their unawareness about the need to innovate their business model and/or reluctance in rethinking their role in the market.

Thus, despite some criticism about the opportunity for established companies to pursue breakthrough innovation strategies [28], the literature acknowledges the advantages gained by reinventing the business model. In such context two issues seem to provoke the most severe limitations for systematically designing business model innovation projects.

The first concern regards the consistent lack of analysis and understanding about business models and their innovation, as claimed by Teece [14]. According to Magretta [8], the literature concerning business models innovation is rich of market triumphs that highlight successful initiatives or intuitions of industrial leaders. On the contrary, limited research has been conducted with the aim of formalizing the determinants that allow the success of business models.

The second concern is related to the different and sometimes contradictory meanings attributed to the term "business model" in the course of time. The diverging interpretations of the concept have consequently led to the emergence of differentiated measures to pursue innovation initiatives. However, according to Keen and Qareshi [94], a general consensus seems to have been reached, representing a business model as a hypothesis "of how to generate value in a customer-driven marketplace". Thus, although the matter may not be undisputed, the concept of value proposition is definitively strictly related with the tasks involving business model innovation. Such interpretation follows in the footsteps of innovation scholars [68], assessing that fundamental breakthroughs require means to deliver a new set of attributes, rather than substantial technological advances. Indeed, disruptive technologies, that underpin the introduction of a new package of attributes, are deemed to show initially lower performances along some dimensions that are valued by established industry customers.

As a result of this diffused vision, the orientation towards customers of innovation programs should not regard the satisfaction of expressed needs, but the research of original and unspoken dimensions of value capable to boost satisfaction. Further insights about the dynamics followed by New Value Proposition (NVP) tasks should therefore be viable to support enterprises that have to undertake customer-centred innovation programs. Definitively, both business and design research involved with New Product Development (NPD) have witnessed a growing interest towards the generation of superior value and experience for the end users [95].

Some investigations have been carried out in order to link the new value attributes to seeded and yet unrevealed needs. In this context, a theoretical background [96] has been built to relate needs theories with the emergence of new attractive customer requirements. In a similar background, studies have been performed to deepen the perception of functional and emotional features of products and services, as well as their relationships with the human needs [97]. As well, Cagan and Vogel [98] have advanced proposals to accomplish NVP strategies based on the interplay of functional and emotional product features. However, the mentioned models result fundamentally descriptive and lack practical indications for the development of products and businesses capable to supply an enhanced customer value.

Within NVP approaches, a branch of business literature e.g. [99] acknowledges the benefits delivered by Blue Ocean Strategy (BOS), fine-tuned by Kim and Mauborgne [100]. Its underpinning theory combines several of the most acknowledged, and previously underlined, concepts within the field of business model innovation: proposition of unprecedented value, redefinition of market boundaries, transition from current industrial standards, etc.

The main assumption of the BOS is that, as supported by the success of mixed Product/Service development initiatives, all traditional industries are already very competitive and capable to oversupply the current demand, needing to look elsewhere for business opportunities. Seeking to 'beat the competition' typically leads to ever-finer segmentation and specialization, price pressure and negative effects on margins. This strategy intends to bring towards the definition of product

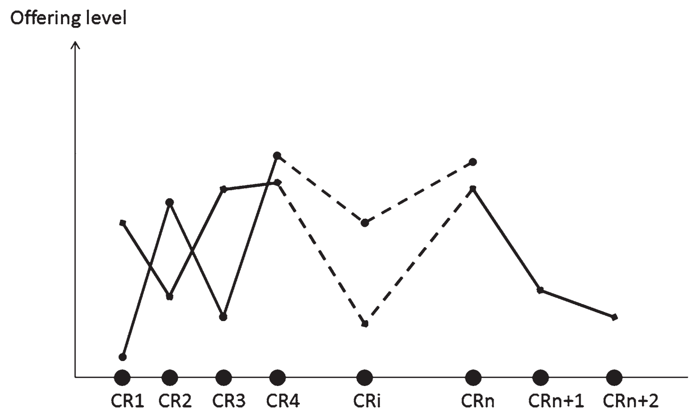

Fig. 1.4 The value curve as a model to represent the dimensions on which alternative profiles compete

characteristics that determine an unprecedented value curve, which strongly differs from the one representing the industrial standard.

The NVP tools that are introduced within the BOS include fundamentally the strategy canvas, graphically depicted through the value curve, and the Four Actions Framework, schematized through the Eliminate Reduce Raise Create (ERRC) Grid. The strategy canvas consists in the general ideas for developing a novel product profile (strategic "move" in BOS jargon). Besides, the value curves stand for the graphical representation of the relative performances of products or services across the relevant factors of competition. The diagram, as that presented in Fig. 1.4, provides a clear vision of the various dimensions of competition (schematized in terms of Customer Requirements—CRs) pertaining two or more alternative product profiles (depicted in grey and black in the graph).

A new curve is built by proper modifications of the current product/service attribute performances and by the introduction of previously ignored properties, throughout the employment of the Four Actions Framework. More in detail, Kim and Mauborgne remark how the Four Actions are applied to product attributes contributing to the buyer's perceived value:

- the eliminate action concerns factors the pertinent industry has long competed on and that do not represent anymore a source of competitive advantage in terms of customer value;
- the reduce action is related to product/service attributes that are overdesigned and that could be provided at much lower performance without affecting perceived value;
- the raise action consists in increasing the performance of certain attributes well above the current industry standard, breaking the compromise with other features of the value curve;
- the create action aims at introducing brand new sources of value for customers.

However, against acknowledged ideas and quite supported assumptions, the BOS currently lacks the systematic paths to envisage innovative products and services, since the introduced tools are elegant to describe past successes, but they are not really prescriptive [101, 102], i.e. they provide just vague indications about the space where to look for new market opportunities. Kim and Mauborgne have illustrated a rich set of case studies from a wide range of industrial sectors, in order to show the strengths of their strategy. Since the authors do not explain how the method has been developed [103], and specifically how they selected the case studies, it has been argued that is not possible to determine whether the examples have contributed to the formulation of the theory or if they have been chosen because they fit the logic of the strategy.

From the applicability viewpoint, whereas it is relatively simple, by benchmarking the competition, to investigate the current relevant product features to be properly removed, worsened or enhanced, the proposition of new valuable product attributes represents a severe challenge [104]. Indeed, it has been argued that the strategy offers just useful visual tools to represent the ideas for exploiting business opportunities, whilst it misses proper guidelines in order to select successful value propositions among multiple alternatives [105]. As a consequence, assessing a strategy canvas results in a difficult matter [106, 107]. Several scholars [108–110] have attempted to improve the robustness of the process of building the strategy canvas, taking into account the extent of importance levels attributed to competition factors in terms of customer perceived value. However, these measures can be adopted just after the relevant business features have been identified and defined, so when the range of possible choices has already been consistently reduced and the actions to be applied have just to be prioritized.

Further matters about BOS applicability and reliability concern the:

- choice and the correct definition of competing factors to be subjected to the actions [111];
- limited rigor about the intended purposes, e.g. regarding the aim of achieving both differentiation and low cost and the exposition of case studies whereas prices have steadily grown;
- the coherence about the strategy recommendations and the illustrated examples, e.g. the claimed need to use all the four actions and strategy canvas showing just Raise and Reduce measures.

Additionally the authors claim that numerous NVP cases, resulting in clamorous flops, can be explained ex-post as outcomes of the application of BOS tools. Thus, the techniques and the basic ideas of Kim and Mauborgne's diffused consulting strategy do not result sufficient to carry out NVP initiatives leading to roaring successes.

The achievement of a robust strategy to support NVP tasks cannot therefore disregard a more careful appraisal of the dynamics followed by successful marketed items and wrong business ideas, since, as remarked by Boztepe [112], the individuation of the proper user factors to be considered in order to provide greater value still remains an open issue.

1.3.3 Summary of the Open Issues Within Product and Process Reengineering

Given the above presented survey of reengineering methodologies involving both product/service and processes, we can state that:

- different kinds of innovation happen according to different stages of product maturity and market penetration;
- the focus on customer value represents a relevant issue within industrial redesign activities;
- traditional BPR initiatives, with the unique aim of reducing process expenditures, show relevant risks due to the disregard of customers, stakeholders and employees;
- beyond the great amount of aspects to be taken into account within reengineering experiences, qualitative variables and uncertainty matters constitute a considerable hurdle in reliably supporting decision making by the means of mathematical models;
- the efforts paid to gather information about customer preferences often result in marginal innovation obtained throughout optimization means;
- within NPD, the proposition of original product profiles characterized by new packages of value attributes, meets the need, expressed by management science community, to design business model innovations strongly differentiating from current market offer;
- among successful NVP experiences, a particular branch involves the integration of servicing within the offer of manufactured products; however no procedure has been acknowledged as a suitable practice for achieving such kind of value innovations;
- generally speaking, the patterns followed along the definition of appealing product profiles lack a comprehensive understanding, which is required in order to formalize methodologies for the generation of superior customer value.

1.4 Purpose of the Book

In this context the development of IPPR reflects the need to plug the gap of the theory about redesign of products and processes and represents a contribution for industries in terms of a support mechanism for undertaking conscious decisions about the directions to be followed within innovation tasks.

As summarized in Fig. 1.5, IPPR orientates the choices to be made along reengineering activities, on the basis of value criteria, by answering the following questions:

- what should be changed in the business process, built as a sequence of industrial phases, in order to effectively fulfill customer requirements or even boost the perceived satisfaction?
- what should be changed in the mix of offered products and services, depicted as a set of attributes, in order to deliver superior value?

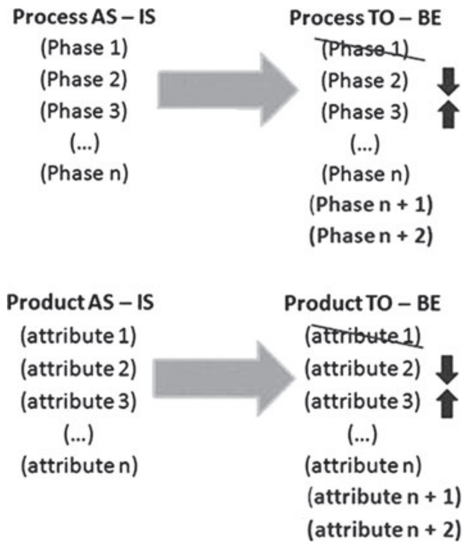

Fig. 1.5 Models of the problems to be solved in a BPR initiative based on value innovation

- which investments and business modifications should be prioritized for implementing the new design of the product or the process?
- which established methodologies and tools can result appropriate for the business transformation, according to the new ideas?

In order to identify the most favourable patterns to rethink the process and the products, thus guiding to the generation of the feasible technical and organizational solutions, it is required to carry out an insightful analysis of the current business by performing:

- the investigation of the AS-IS business process at both the economical and technical levels;
- the survey of currently met customer needs and expectations and the individuation of further requirements to be fulfilled with reference to product lifecycle;
- the identification of the bottlenecks in the generation of the value, determining if the product or the process are liable of the main business difficulties.

From a methodological point of view, the previous tasks require the definition of suitable techniques and tools, such as:

- modeling techniques capable to summarize the whole set of information and data pertaining different domains;
- value assessment metrics by which to perform the analysis of the business process focusing on the value delivered to the customer;
- criteria to guide NVP tasks for products and services;
- instruments to support the technical implementation of the reengineering initiatives.

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Chapter 2
IPPR Methodological Foundations

2.1 Introduction

The analysis and solution model underpinning IPPR consists in a set of activities that are organized along a common path for each class of reengineering problems, as clustered in the previous Chapter.

Basically IPPR method follows a well established logic which is universally acknowledged as a standard to analyze and solve technical problems. It is grounded on three main phases: (i) situation analysis and representation of the relevant information; (ii) identification of the system criticalities; (iii) individuation of the suitable solving directions. The aim of IPPR is to perform the step-by-step procedure with a constant orientation towards what concerns customer value and perceived satisfaction. To this end, the whole body of the methodology suggests suitable tools and techniques.

However, given the consolidated logic adopted by IPPR (i.e. *analysis* of the problem, *diagnosis* of the reengineering opportunities, *synthesis* of the solutions), each task can be performed by the usage of alternative instruments dedicated to the design of products and processes. Thus, the reader can use his/her own body of knowledge to carry out the activities consistent with IPPR, with regards to his/her competencies in the fields of business process reengineering and new product development. Otherwise, the user can benefit from the original tools illustrated in Chap. 3, which highlights the preferred employment of value-oriented instruments for each step of the methodology.

According to the objectives of this Chapter, the introductory parts of the Subsections belonging to 2.2 report an overall description of IPPR by providing an overview of the main methodological steps and their partial outputs. Subsequently, the remaining content of the Subsections reports a detailed description of the tasks, activities, expected results foreseen by each step of the methodology. As a whole, the presentation of the coverage is organized on the basis of the classification of the business problems already introduced in Chap. 1.

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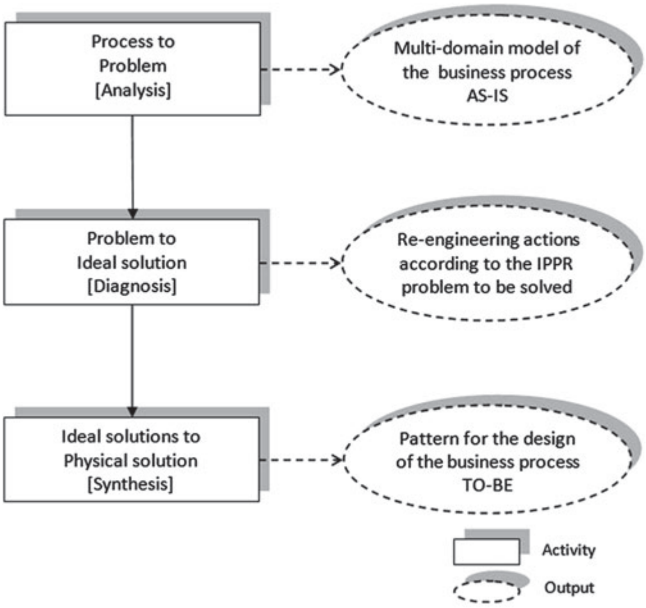

Fig. 2.1 Workflow and partial outputs of IPPR methodology

As a result of the description of IPPR structure, the main activities to be carried out are summarized in Sect. 2.3.

2.2 The Logic and the Structure of IPPR: Steps, Activities and Outcomes

IPPR methodology leads the user to the identification of feasible process/product innovations by means of an analysis and solution path based on three main steps. The workflow of activities and the arising outputs are depicted in Fig. 2.1.

However, in order to successfully carry out the depicted activities, IPPR practitioners are requested to preliminarily acquire the information about the problem to be investigated. With this aim, the Sect. 2.2.1 discusses the objectives to be attained with regards to the collection of the essential elements of knowledge.

The aim of the *Process to problem* step is to obtain an exhaustive description of the AS-IS situation by investigating the industrial operations and their outputs. The result of this phase is constituted by a model of the business process capable to represent all the aspects related to both the functional and economic domains. Such a multidimensional approach allows to manage the cross-disciplinary nature of the

Table 2.1 Organization of the content related to each phase of IPPR methodology within the present Chapter in function of the class of business process problem to be addressed

	Problem to process	Process to ideal solution	Ideal solution to physical solution
Class 1 and Class 2	2.2.2.1 2.2.2.2 2.2.2.3	2.2.3.1	2.2.4.1
Class 3	2.2.2.2 2.2.2.3	2.2.3.2	2.2.4.2

business process. This is the key feature enabling a comprehensive analysis of a large amount of common industrial problems.

The loss of competitiveness of a business process occurs when the provided outputs are no longer able to satisfy the customer expectations, nor to attract market segments through appealing and original product designs. The causes that determine such situation have been already extensively described in Chap. 1 and, generally speaking, they may be related to aspects falling into the sphere of industrial process and/or of the delivered product. Such causes represent what we can call *value bottlenecks*, since they somehow impact (negatively) the customer perceived value.

The second step, named *Problem to Ideal solution*, is focused on the clear identification of the recalled value bottlenecks and eventually of potential innovation opportunities. Moreover, once the critical aspects of the business process have been analyzed, proper reengineering actions are defined in order to remove the value bottlenecks and preserve or regain the market competitiveness. These guidelines are expressed in the form of new process requirements for the problems belonging to the class 1 and 2, while they are depicted as directions for the transformation of product profiles, with reference to the class of problem 3. The emerging hints represent the inputs of the subsequent design activities which are aimed at identifying suitable technical solutions for the implementation of the ideas of the new process or product.

The last step, namely *Ideal solution to Physical solution*, suggests the suitable and acknowledged instruments to support the design activities of the physical solutions concerning the introduction of new industrial process phases, the improvement of the existing ones, the reorganization of the resources allocation programs, the production of innovative items and the delivery of novel services.

The sequences of activities summarized in Fig. 2.1 are customized according to the business process problem that should be addressed. Table 2.1 indicates the sections of the present Chapter in which the reader can find the relevant criteria to shape each step of the IPPR methodology according to the class of reengineering problems defined in Chap. 1.

Table 2.2 Checklist providing the overall set of relevant information to be gathered according to the class of problem to be faced

Problem to be solved	Information to be gathered
Class 1 and Class 2	Phases of the business process
	Flows of materials, energy and information
	Elapsed duration of each phase, labour time, dead times
	Involved technologies
	Occupied space
	Involved human skills and knowledge
	Other phase expenditures
	Control and evaluation parameters governing each phase
	Customer requirements and their relevance in determining the customer perceived value
	Contribution of each phase in determining the product requirements
Class 2	Determinants for delighting the customer
	Determinants for avoiding the customer dissatisfaction
Class 3	Product attributes of the treated product and of the competing ones
	Performances levels at which the product attributes are delivered
	Kind of benefits perceived by the user in delivering product attributes

2.2.1 Performing Information Gathering for IPPR

The information gathering is a preliminary activity to be performed in order to widen the knowledge of the IPPR user about the business problem to be treated. The additional information to be collected with the aim of carrying out the subsequent tasks in a more rigorous way strongly depends on the nature and the role of the practitioner (product manager, analyst, CEO, researcher, etc.) and thus on the main individual lacks of knowledge.

In order to address the sources of information to be preliminarily consulted, Table 2.2 summarizes the aspects to be treated within IPPR with reference to process and product reengineering.

Commonly, the activity is carried out by taking in consideration several information sources. At the beginning of the information acquisition, sources like books, reports, manuals and catalogues play a significant role for the definition of the background of the industrial sector to be analyzed [1]. Subsequently, more detailed and explicit information can be extracted through the consultation of domain experts and involved personnel [2].

The ideal result of the information acquisition would be the extraction and codification of tacit knowledge, which plays a significant role especially within the description of processes, by highlighting human practices when performing operations. The concept of tacit knowledge was introduced by Polanyi [3], who defined it as personal, with no possibility to be codified. Since then, the possibility of acquiring and disseminating tacit knowledge is a very debated issue. Many scholars, such as Nonaka [4], have developed Polanyi's conception of tacit knowledge in a practical direction to enhance organizational knowledge creation, assessing the possibility to elicit it. Coherently to this vision and purpose, the task of acquiring tacit knowledge implies to meet directly the employees; the consultation on the shop floor recalls the concept of "gemba", a Japanese term meaning "the place where the truth can be found", firstly introduced by Mazur [5] within Quality Function Deployment (QFD) [6].

Also when the attempt of collecting elements of tacit knowledge results an excessively challenging and time-consuming task, it is recommended to take into account the viewpoint of multiple experts. However this can result in contradicting issues arising from overlapping competencies of the involved specialists. In order to overcome the difficulties dictated by the emergence of conflicting visions, different approaches can be chosen:

- a final conjoint consultation of the experts can be organized to conciliate the diverging viewpoints;
- IPPR steps 1 and 2 can be performed separately by multiple experts and then the resulting reengineering directions are compared and integrated;
- with reference to the classes of problem 1 and 2, which employ more quantitative coefficients, statistical tools generally dedicated to deal with uncertainty can be favorably employed to the outcomes of steps 1 and 2, leading to a "best" description and analysis of the process.

2.2.2 Process to Problem Phase

The aim of the first step is to schematize the business process into a general model of the problem, allowing to perform the subsequent analysis steps foreseen by the IPPR methodology.

Such a model describes how the system works in both the technical and economic domain. It summarizes the sequence of the performed phases and their mutual relationships expressed through the flows of inputs/outputs and involved resources such as: material, energy and information, technologies, human skills and know-how, elapsed times and monetary expenditures.

The final outputs of the process are represented by the customer requirements which are fulfilled by the manufactured products and delivered services. These attributes are depicted throughout their performance or offering level and their relevance in determining customer satisfaction and/or avoiding buyer's discontentment. The Fig. 2.2 shows, in a schematic way, the input data and a conceptual representation of the output model provided by this step.

In order to accomplish the above mentioned objectives, the *Process to Problem* step requires the execution of the following specific activities:

- industrial process modeling;
- product information elicitation;
- product modeling.

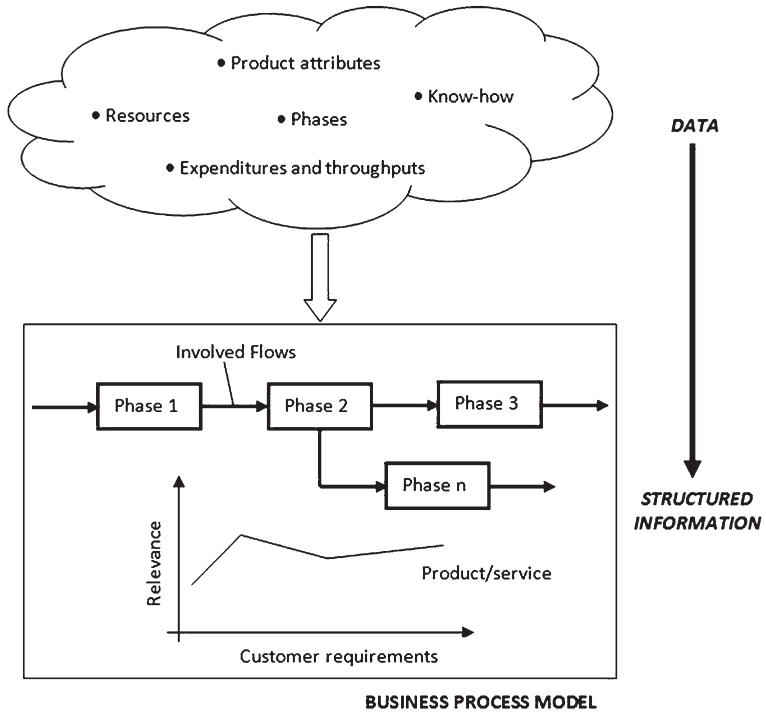

Fig. 2.2 The "Process to problem" step brings to the definition of a model of the business process (from both the industry and the customer perspective) in both the technical and economical domains. This model is used to perform all the subsequent analysis tasks

Here in the followings these tasks are described in detail, according to the class of reengineering problems to be addressed.

2.2.2.1 Process Modeling

For the problems belonging to the classes 1 and 2, the collected data have to be organized in order to build the process model, a structured representation of the AS-IS situation. Several representation methods with diverging formalisms are available in the literature to support the modeling of industrial activities. However, the various techniques significantly differ in the ability to model the system according to different domains and perspectives. Some techniques focus primarily on the data flows, others on the deployed functions or on the assigned roles of human resources within the process, etc. [7, 8].

A customized multi-domain model, presented in Chap. 3, is suggested to represent the information and data needed to implement the IPPR methodology. Its advantages arise as a result of the hybridization of different modeling techniques, each one tailored to represent different facets of a business process.

Whereas the user would prefer the employment of mastered modeling techniques, the representation of the process has to include at least the following important aspects:

- *Functions*: the model has to report the process phases in terms of performed functions, input and output flows;
- *Multi-domain features*: for each phase of the industrial process, the model has to summarize the involved flows of resources in both the technical (i.e. flows of energy, materials and information) and economical (i.e. monetary flows or equivalent indicators) domains;
- *Control variables and performances*: the model has to allow a clear representation of the control parameters governing each process phase (e.g. cutting speed of a machine tool, bill of materials), as well as the required performances.

2.2.2.2 Product Information Elicitation

The information that is schematized within the process model (classes 1 and 2) supports the identification of a large set of features that the product should have. Indeed, the designed transformations of channeled resources into desired outcomes are justified in terms of the fulfillment of the customer requirements. However, in order to represent a comprehensive record of the process outputs in terms of the elements that currently participate to the building of customer value, suitable checklists are proposed within this step of IPPR.

Furthermore, with the objective of accurately characterizing the business process, the elicitation is a crucial activity of the relationships existing among the phases and the terms contributing to the perceived customer value. At the firm level, the phases can be considered like the segments that constitute the value chain, as defined in the literature by Porter [9] and some other scholars. According to this concept, each function performed along the investigated process contributes in fulfilling the characteristics of the final product or service, thus in the generation of value. Basically, the extent of such a contribution depends on the number of properties of the elaborated inputs that are modified by the function, as well as by the magnitude of such changes. In the context of product development strategies, the recalled QFD investigates the interplay among customer expectations and engineering characteristics that meet the needs of the end-user. With a similar logic, the proposed task requires mapping the features underlying the accomplishment of each customer requirement. Subsequently the phases, properly identified in the modeling step, that modify or deal with those features are monitored by the business process experts in order to define their accounted ratios in fulfilling the customer requirements (CRs). For instance, the requested speed of a courier service is achieved by the correct functioning of all the phases impacting the delivery time of some goods, thus all the operations concerning the scheduling, the warehousing and the transportation of the sent items. The relative contributions

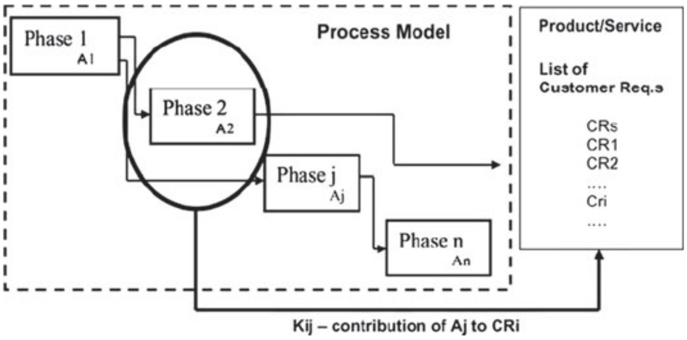

Fig. 2.3 The coefficients k_{ij} represent the contribution of the j-th phase to the satisfaction of the i-th customer requirement

addressed to the j-th phase in ensuring the achievement of the i-th customer requirement (CR) will be further on indicated with the variable k_{ij}. As represented in Fig. 2.3, the coefficients k_{ij} can be evaluated as a correlation between the properties of the objects modified by each function and the CRs of the final product.

With reference to the problems concerning product reengineering (class 3), the objective of the activity is the elicitation of the information related to the dimension of customer satisfaction. A suitable tool is proposed with the aim of individuating the circumstances potentially guiding to the emergence of sources of value, regardless they have been already exploited or not. The structured search should therefore lead to the individuation of a comprehensive set of offered product attributes and, eventually, if required by the case study, to ease the monitoring of the competition. Additionally, the mapping process may allow the discovery of disregarded performances or characteristics, thus facilitating the task of designing a new product profile.

2.2.2.3 Product/Service Modeling

The product model summarizes the offered value profile according to the competing factors of the market where the business process operates. This activity is aimed at identifying the product attributes delivered to the customer, their relevance and role in determining the customer satisfaction.

Within IPPR, different representations are adopted for the process related problems (classes 1 and 2) and product oriented reengineering tasks (class 3).

The first circumstance requires a description of the process output in the perspective of the company, by shedding light on *how much* the product delivers value or avoids dissatisfaction. A basic activity concerns therefore the classification of the customer requirements through a criterion capable to highlight the extent in impacting the customer contentment. As widely acknowledged in

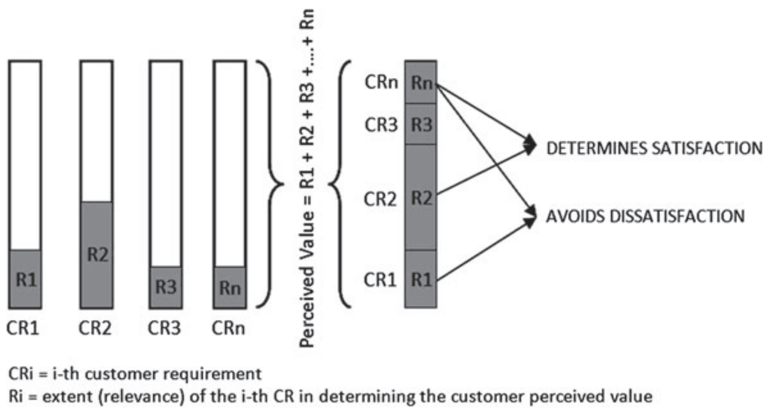

Fig. 2.4 The classification scheme of the customer requirements according to the relevance in determining the customer perceived value and the role played in impacting the customer satisfaction/dissatisfaction

the literature [10], some product characteristics are able to generate satisfaction for the end-user, while the presence of some other characteristics is merely motivated by the need to avoid the customer dissatisfaction. Moreover, the extent in determining the customer satisfaction and/or avoiding dissatisfaction depends on the importance of each product feature within the perceived value. Thus, the twofold properties characterizing the customer requirements suggest the adoption of a scheme (Fig. 2.4) to describe the attributes in terms of:

- the extent (relevance R) at which they impact the customer perceived value;
- the role in determining the customer satisfaction and avoiding the product rejection.

Nevertheless, certain circumstances can invalidate the prerequisites for which the distinction is meaningful between attributes aimed at, respectively, generating satisfaction and avoiding discontentment. Such conditions characterize all business processes intended to fulfill just customer requirements imposed by regulations, standards or requested by the purchaser (i.e. for third-parties or suppliers), as well as merely focused at replicating the performances of the products in the marketplace. Beyond imitation, the last case is common for companies facing the need to achieve certain product characteristics to stay competitive, but whose business is affected by unpredictable external problems (e.g. shortage of materials, soaring prices of certain required resources, etc.). Thus, whenever the reengineering task is oriented towards the achievement of predefined targets, ranging outside the sphere of the company decisions, the qualitative classification of the role played by the product features in impacting the customer satisfaction misses the original sense. According to this assumption, all the business process problems falling into the first class do not require the classification of the customer requirements, being the definition of the relevance scores sufficient to characterize their contribution in building value.

Among the classification hypotheses regarding the different kind of features determining the customer satisfaction, the model employed by IPPR adopts the categories introduced by Kano et al. [10], representing the most established clustering criteria available in the literature.

With the aim of supporting the problems belonging to class 3, a suitable representation of the product profile is proposed, which emphasizes *how* the attributes deliver value and whether their offering level is adequate for the current demand from the customer viewpoint. For the scope of product reengineering, a suitable clustering of the fulfilled attributes supports the identification of the most favorable directions to attain new value profiles. Such a categorization concerns the distinction of the product features according to the functional role played in determining positive outcomes for the customer, in avoiding limitation of undesired effects or in giving rise to the reduction of required resources, with reference to the terms that contribute to "Ideality" as suggested by TRIZ [11].

2.2.3 Problem to Ideal Solution

This step is aimed at identifying "what should be changed" in the AS-IS business process in order to increase the benefits for the company, as a result of the enhanced customer value. The customer satisfaction is evaluated as a direct function of the delivered product attributes.

As recalled, according to the classes of reengineering problems defined in Chap. 1, the actions to be undertaken may regard the process, the product or both of them.

The faced difficulties regarding the process may concern the hurdles in entering a new market due to under capacities in providing mandatory product characteristics (class 1) or the loss of competiveness for a consolidated business (class 2). In both circumstances this step is aimed at highlighting the value bottlenecks that hinder the maximization of the customer satisfaction according to the available resources and the buyer demands. This analysis is the starting point for the effective reorganization of the process pursuing the increment of the value delivered to the end-user.

Otherwise, if the lack of competitiveness is due to a product that is definitively no longer capable to appeal the marketplace, it is necessary to define a new value profile. The redesign of the industry outputs can be obtained by rethinking the overall business model and, more specifically, by identifying the product characteristics that can be worthily introduced, emphasized or eventually removed without particular consequences.

With reference to the classification of the industrial problems suggested in the Chap. 1, the implementation of the following tasks is required:

- *Identification of what should be changed in the process*: it is required to solve business problems related to the competitiveness of the industrial process, i.e. problems belonging to the classes 1 and 2.
- *Identification of what should be changed in the product*: it is required to solve problems of product competiveness, i.e. problems falling into the class 3.

In the following paragraphs the activities aimed at identifying what should be changed in the process or in the product, are described in detail.

2.2.3.1 Identification of What Should Be Changed in the Process

Value Engineering, the well known methodology developed by Miles [12], represents a useful starting point with the purpose of identifying the business shortcomings. However, according to the considerations performed in Sects. 2.2.2.2 and 2.2.2.3, the value assessment strategy suggested by Miles requires a shift in order to be employed for the aim of IPPR, from the system perspective to the viewpoint of generated customer satisfaction. More precisely, instead of considering the revenues (as a function of the technical performances) provided by the process functions and the spent resources, the generated benefits should be measured in terms of satisfaction for the customer. Within this vision, the logical path followed by IPPR to identify process bottlenecks, is constituted by three main activities as shown in Fig. 2.5. The involved tasks allow the assessment of the phases' worthiness by exploiting the information gathered in the *Process to Problem* step.

With reference to the industrial problems grouped within the class 2, the coefficients k_{ij} give the possibility to evaluate for each phase suitable indexes, namely *Phase Customer Satisfaction* (PCS) and *Phase Customer Dissatisfaction* (PCD), that express the potential to bring customer contentment and the contribution in avoiding dissatisfaction. Such values represent, respectively, the opportunity for a phase to delight customers and the risk to harmfully impact the product perception. Thanks to PCS and PCD it is possible to determine the contribution of each phase to the general customer contentment by means of an indicator named *Phase Overall Satisfaction* (POS), which is assumed as a measure of the benefits provided by the phase.

A review of the literature shows the availability of metrics for the calculation of indexes to evaluate overall appreciation of products as a function of the terms expressing positive and negative evaluations by the customers (such as PCS and PCD, respectively). Commonly the impacts of satisfaction and (avoided) dissatisfaction are related through linear and non-linear equations to the overall satisfaction. Among them, the one receiving the widest consensus has been obtained through a research work performed by Mittal et al. [13] and has been adopted as a reference for the IPPR methodology. The employed equation is non-linear and it states the asymmetric influence of positive and negative evaluations, with a greater role played by dissatisfaction factors in impacting the general customer

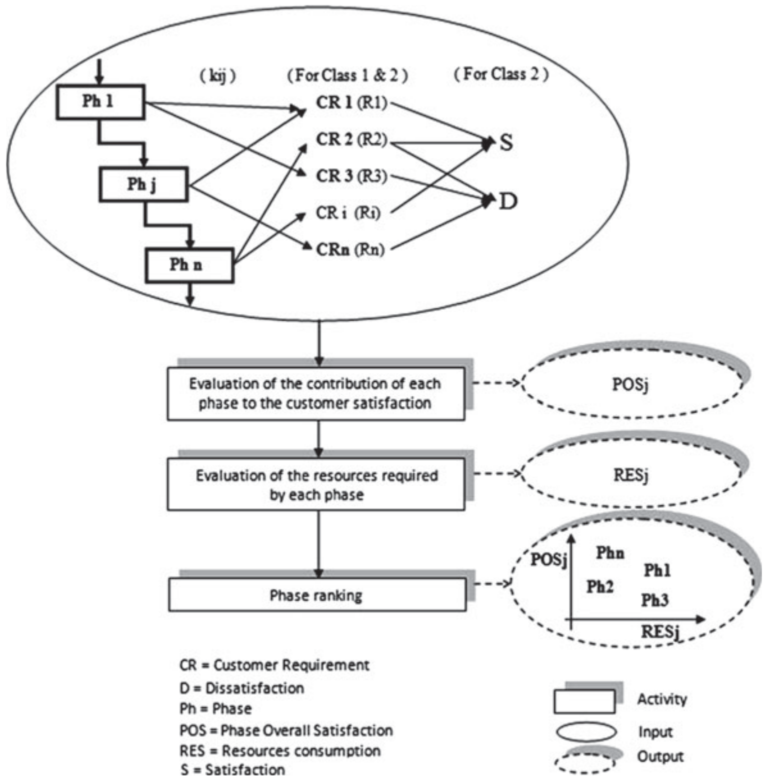

Fig. 2.5 The logical path suggested by IPPR in order to identify what should be changed in a process

contentment. More details about such model and the metrics adopted for the calculation of PCS and PCD coefficients are provided in Chap. 3.

For the business problems categorized within the class 1, due to the missing of diverse contributions to satisfaction and discontentment, the calculation of the POS is performed by taking into account just the k_{ij} coefficients and the relevance indexes R of the attributes.

Once the POS coefficients have been calculated, the next step requires the evaluation of the resources spent by each phase and eventually the estimation of undesired effects resulting as the process is displayed. Within the context of business processes it is suitable to consider the whole range of resources (occupied space, information and know-how, labor, energy, materials, dead times) and measure their extent, in order to use value formulations for calculating quantitative indicators. Long elapsed times to perform the phases represent relevant hurdles for the business, especially for those industries (e.g. fashion), and kind of firms (e.g. third-parties, suppliers) for which timeliness is a crucial competing factor. All the other kinds of employed resources can be compared in terms of the resulting expenditures, so to be evaluated with uniform units of measurement. With regards to significant harmful effects and their consequences (e.g. pollution and measures to limit its impact, noise, need to introduce particular safety systems), they have to be soundly considered as undesired elements within the business process and its phases. In certain cases they can represent even barriers to carry out the process and then to access the market. In other circumstances the harmful functions can occur in the shape of problems affecting the stability of the system, as well as the repeatability of the process.

When monetary costs, meaningful elapsed times and harmful effects coexist in the business process, experts have to weigh their relative relevance, introducing corrective coefficients for the overall estimation of undesired issues. Further on, with the term *resources*, we will indicate the total mix of expenditures, drawbacks and inconveniences that emerge as the phases of the business process are displayed.

Thanks to the results obtained by the previous assessment activities, it is possible to characterize the phases constituting the process in terms of generated benefits versus spent resources. The insightful analysis of the phases leads towards the individuation of the process bottlenecks in a value-wide perspective.

The ratio between POS and the spent resources provides an *Overall Value* (OV) index suitable to globally identify strengths and weaknesses of the process. Those phases showing a high OV can be considered to be tailored to the business process and their employed resources are well spent in generating customer satisfaction, whereas the ones with low scores represent problematic issues.

The conjoint analysis of the POS and the spent resources helps in characterizing the nature of the bottlenecks: when a low OV is due to a high denominator, i.e. great amount of resources, the focus of the reengineering actions must be oriented towards saving policies. Besides, when a poor OV rate is due to a limited contribution to customer satisfaction, the reengineering initiatives should evaluate the opportunity to eliminate the investigated phase by assigning other segments of the process its functions, substitute the technology adopted so far, introduce new features to be fulfilled without a meaningful increase of the needed resources.

With reference to the reengineering problems pertaining class 2, it is possible to perform further evaluations of the phases, by considering separately, with reference to the spent resources, their capability to achieve customer satisfaction and/or to fulfill the basic requirements of the product. A tailored graphical representation introduced within IPPR illustrates the coupled appropriateness of the process phases in delighting customers and avoiding their dissatisfaction.

In the Chap. 3, all the models and formulas to determine the above described parameters are provided, as well as the suggested representation diagrams.

2.2.3.2 Identification of What Should Be Changed in the Product

Such task refers to the most critical activity involved in the New Product Development cycle.

As stated in the previous Chapter, most of the methods developed to support NPD initiatives are based on the so called "Voice of the Customer" (VoC). The business strategy based on this approach entrusts the main choices of innovation task to the end-user of the manufactured product or the delivered service. However, as noticed in Chap. 1, the VoC commonly brings just to the design of incremental innovations, bounded within what customers can already conceive. As a consequence breakthrough solutions, capable to provide substantial competitive advantages, are not diffused.

These evidences have been confirmed also by several scholars in the field of product innovation management. They have demonstrated that business strategies based on the definition of an innovative set of product features for the reference industry of the company, allow to create new market space by performing a New Value Proposition (NVP). Hence, aiming at radically modifying the product, the tools suggested by IPPR for the third class of business problems are oriented towards the achievement of a strategy based on NVP, rather than being addressed to the fulfillment of explicit needs.

With this scope, the most critical aspect related to NVP initiatives is represented by the definition of the new elements of value to be delivered to the customer. As recalled in Chap. 1, the most established approaches, such as those swiveling on increased servicing (PSSs, SPE), represent just a specific strategy within the creation of new value for customers. On the other hand, despite the general appraisal received in the industrial world, the tools proposed by the BOS are affected by scarce applicability, since their nature is predominantly descriptive rather than prescriptive.

In order to overcome the limits of the recalled methodologies an original tool has been developed within IPPR, namely *New Value Proposition Guidelines* (NVPGs). It consists in a set of recommendations capable to orientate the strategic decisions about the definition of a new product profile. The NVPGs, by complementing the general scheme offered by the Four Actions Framework (FAF), identify which value shifts result the most advantageous with respect to the consolidated industrial standards.

The NVPGs have been developed by performing an in-depth analysis of successful market stories, aimed at pointing out common patterns of value evolution. More in detail, the performed survey has individuated which categories of competing factors are preferentially transformed within the treated value transitions, according to the functional features.

On the basis of the performed classification, the NVPGs provide a collection of suggestions in terms of types of new valuable product attributes to create, existing properties to enhance, current features whose performances are viable to be reduced and eventually product characteristics to be eliminated without relevant drawbacks. Hence, the guidelines represent useful recommendations to support value transition tasks within strategies based on business model innovation and NVP.

2.2.4 *Ideal Solution to Physical Solution*

This step of IPPR addresses the application of the appropriate measures to attain the new process/product specifications, as a result of the *Problem to Ideal Solution* phase. The emerging indications have to be translated in technical objectives and organizational changes, allowing to put in practice all the needed business process modifications.

Thus, the objective of this step is the identification of the proper functions to be performed and the search of appropriate technical solutions for their implementation.

According to the class of business process problems to be addressed, the *Problem to Ideal Solution* phase consists in the following tasks:

- Class of problems 1 or 2: finding physical solutions for process reorganization and resources allocation.
- Class of problems 3: finding physical solutions for implementing the new product profile.

In the following subsections some references about appropriate methodological approaches are provided in order to guide the reader in the selection of the most suitable instruments to support the aforementioned activities.

2.2.4.1 Finding Physical Solutions for New Process Implementation

The value indexes, extracted as seen in Sect. 2.2.3.1, address the patterns for the overall reengineering of each phase of the business process. As already recalled, the directions to be followed can be classified in three main categories:

(1) Increasing the phase value through the improvement of its performance or in terms of efficiency, i.e. through the reduction of the involved resources, while preserving the same benefits. Such objective is classically pursued by technological enhancements, more efficient organization systems, broader employment of ICT to optimize the flow of resources within the process.
(2) Increasing the phase value by supplying new customer requirements. The scope can be attained by exploiting partially used resources or by-products in fruitful ways, capable to head towards the generation of additional features. With such aim, the business process model represents a suitable starting point for the individuation of not fully exploited resources.
(3) Suppressing low value phases, with the consequent modification of other process sections which are the candidates for the fulfillment of the consequently unsupplied customer requirements. In order to perform the task, it is useful to highlight further phases employing similar kinds of resources, technologies, know-how.

According to the above objectives, the authors put forward a set of acknowledged methodologies, aimed at addressing the task of identifying conceptual solutions.

Classical TRIZ tools, e.g. the *76 Standard Solutions* [11], represent suitable instruments to increase the performance or the efficiency of the phases (directions 1 and 2). More precisely, once the critical function of the phase to be enhanced has been identified, the Standard Solutions constitute general strategies to increase its effectiveness, through the introduction or modification of appropriate substances and/or fields (standards belonging to class 1.1) or through a more efficient use of the existing resources (standards belonging to class 2).

Many methodologies deal with policies within manufacturing environments and they are mostly tailored to reduce useless resources, so that they address the first direction for phases modifications. In this context, *Lean Manufacturing* [14] and *Quick Response Manufacturing* (QRM) [15] provide valuable suggestions for business improvements. Lean Manufacturing proposes a large set of tools that aim at reducing wastes, meant as those activities carried during the production stages that do not bring any added value. Lean Manufacturing introduces a pull-based supply chain, whereas procurement and production are demand driven and thus coordinated by actual customer orders. The supplying and the purchases are ruled by *Just in Time* (JIT) strategy that aims primarily at the reduction of in-process inventory. Besides, the reduction of the operational times can be obtained through the means of QRM, whose target is the minimization of lead-times. In order to provide further benefits, QRM methodology should be applied to the whole supply chain, strengthening the cooperation among the involved business units that participate in the generation of the value.

The assignation of new properties to a certain phase can be supported by the individuation of existing techniques in dedicated knowledge bases. Scientific documents and especially patents represent the widest available source of technical information close to the technological frontier. The individuation of proper ways to put in practice additional features of the phases can be done also with function retrieval tools. In the scope of TRIZ, *Function-Oriented Search* (FOS) [16] is especially suitable to find and apply existing functions, also from different technical fields. FOS is an evolution of the TRIZ concept assessing that the shortest path to an effective solution is to use an analogy. The tool leads the user in the identification of the key problem, the formulation of a generalized function to be achieved, the individuation of the most appropriate industrial area to be investigated, the selection of the technologies closest to required functional parameters.

2.2.4.2 Finding Physical Solutions for New Product Implementation

According to the results coming from the previous step of IPPR, a new set of product specifications in terms of value attributes is obtained. Thus, before performing any conceptual design activity, such attributes must be translated in candidate Engineering Requirements (ERs) of the new system. Among the others, a useful method used to support the preparation of the ERs list is the QFD, that helps

Table 2.3 The chart summarizes the flow of activities foreseen by IPPR for each class of BPR problems to be addressed

Phase	IPPR activity	Class of problems 1 and 2	Class of problems 3
Step 1			
Process to problem	Process modelling	•	
	Product information elicitation	•	•
	Product/service modeling	•	•
Step 2			
Problem to ideal solution	Identification of what should be changed in the process	•	
	Identification of what should be changed in the product/service		•
Step 3			
Ideal solution to physical solution	Finding physical solutions for new process implementation	•	
	Finding physical solutions for new product/ service implementation		•

to translate customer wants into product requirements. Moreover, through the QFD, the designer can have a clear vision of the criticalities related to design problem, since these tools allow the identification of any positive or negative correlation among the product requirements. Along the translation of customer requirements into engineering specifications, an iterative process is common to refine both lists, e.g. by highlighting possible new advantages arising by the profile conceptualization or the emergence of (at least apparently) mutually not compatible demands.

According to the nature of the design problem and its complexity degree, it may happen that no inventive step is required to obtain the successful solution, but just the application of the knowledge already available within the design team. The recalled TRIZ *76 Standard Solutions* are an excellent structured checklist which allows to browse the team knowledge with a systematic approach. Alternative methods to support this kind of design task are presented in [17].

Besides, if the previous analysis points to the necessity to overcome the emergence of conflicting requirements, the design task requires the application of tools for the identification and solution of contradictions, such as the techniques suggested by the TRIZ [11]. As a result, a conceptual solution is generated in terms of physical properties of the system that allows to satisfy the conflicting requirements according to the available resources.

2.3 Summary of IPPR Flow of Activities

The flow of activities foreseen by IPPR to address the problems of classes 1, 2 and 3, is summarized in Table 2.3, according to what is reported in the previous Section.

The reader can refer to this chart in order to easily identify the relevant tasks involved in each step of the method, that are required to address the faced reengineering problem.

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Chapter 3
IPPR Implementation

3.1 Introduction

This Chapter illustrates the instruments for the implementation of the IPPR activities according to the methodology workflow described in Chap. 2. The instruments involved in each step of IPPR are hereby presented with the aim of clarifying their tailored application according to the three classes of reengineering problems.

The content is structured in three main Sections which comply with the steps of IPPR. Section 3.2 describes the tools that are suggested to carry out the activities foreseen by the *Process to Problem* phase. They deal with the process modeling, the information elicitation about the output of the business which is valued by the customer and the product representation. Then, with reference to the tasks to be performed in the *Problem to Ideal solution* step, Sect. 3.3 shows the instruments that are recommended to analyze the process and the product attributes, as well as to identify the appropriate directions to advantageously reengineer the system in the customer value perspective. Eventually, Sect. 3.4 provides the metrics to select the specific tools which are viable to support the redesign tasks, as foreseen by the *Ideal Solution to Physical solution phase*.

Table 3.1 provides a summary of the techniques proposed for each activity of IPPR, as well as the matching Sections. Thanks to the Table, the user can easily individuate the content which is individually deemed to be the most interesting and useful for the purpose of the reengineering problem to be faced.

3.2 Implementation of the "Process to Problem" Phase

The *Process to Problem* phase includes a set of activities whose outcomes are crucial for the subsequent analysis tasks. As recalled in Table 3.1, they consist in:

F. Rotini et al., *Re-engineering of Products and Processes*,
Springer Series in Advanced Manufacturing, DOI: 10.1007/978-1-4471-4017-7_3,

Table 3.1 The chart summarizes the tools required to perform the activities involved in each step of the IPPR methodology, according to the class of reengineering problems to be addressed

Phase	Activity	Class 1	Class 2	Class 3	Section
Step 1					3.2
Process to problem	Process modelling	Multi-domain modeling technique			3.2.1
	Product information elicitation	CRs checklist, correlation coefficients			3.2.2.1
				Lifecycle system operator	3.2.2.2
	Product modeling	Relevance scale			3.2.3.1
			Kano model		3.2.3.2
				Functional features	3.2.3.3
Step 2					3.3
Problem to ideal solution	Identification of what should be changed in the process	Phase overall satisfaction			3.3.1.1
			Customer satisfaction/dissatisfaction, phase overall satisfaction		3.3.1.2
		Resources consumption			3.3.1.3
		Overall value, POS–RES chart			3.3.1.4
			Phase values, value assessment chart		3.3.1.5
	Identification of what should be changed in the product			New value proposition guidelines	3.3.2
Step 3					3.4
Ideal solution to physical solution	Finding physical solutions for new process implementation	Guidelines to select process redesign tools			3.4.1
	Finding physical solutions for new product implementation			Guidelines to select product redesign tools	3.4.2

The last column shows the sections of the chapter where the user can find the detailed description of the instruments

- *process modeling* is required only for the problems related to classes 1 and 2 and it is aimed at obtaining an overall representation of the business process, capable to summarize the performed functions and the involved resources, the control parameters governing the phases, the employed technologies;
- *product information elicitation* is an activity aimed at collecting the relevant performances concerning the outputs of the business process for the classes of reengineering problems 1 and 2. In order to address the reengineering problems belonging to class 3, the information to be preliminarily organized concerns the value supposed to be delivered by the product within the whole lifecycle;
- *product modeling*: in the case of problems belonging to class 1 it is employed to assess the relevance of each customer requirement in generating the customer perceived value. With reference to the second class of reengineering problems, additional indications are required, concerning the role of the customer requirements in avoiding the buyer discontentment and/or providing an unexpected level of satisfaction. Conversely, when taking into consideration the problems belonging to class 3, the model to be used highlights the features offered to the customer, the ways such attributes deliver value and their performance levels.

Section 3.2.1 provides the description of the tools to support the information gathering, Sect. 3.2.2 illustrates the instruments employed to model the industrial process and eventually Sect. 3.2.3 describes the tools dedicated to the product modeling.

3.2.1 Multi-Domain Process Modeling Technique for Classes of Problems #1 and #2

The process modeling is a fundamental activity in order to address the reengineering problems belonging to the class 1 and 2, since its outcomes constitute the pillar on which the subsequent analyses are grounded.

As widely discussed in the previous Chapter, IPPR requires an exhaustive representation of the industrial process from both the technical and economic perspectives. To this end, the adopted technique merges together the flows of inputs/outputs relevant for the process analysis, classically represented through *IDEF0*, *Energy Material Signal* (EMS) and *Theory Of Constraints* (TOC) models. Such a schema allows the organization of a comprehensive set of information related to technical and economical domains in an overall frame capable to provide a detailed representation of the resources and monetary flows, expected outcomes of the phases, control parameters, involved technologies, etc.

The multi-domain technique is here presented focusing the attention on the features which are interesting for the process modeling within the context of IPPR, however the user can refer to the description of the IDEF0, EMS and TOC models reported respectively in the Appendixes A, B and C, to deepen his/her knowledge about the original scopes of these techniques.

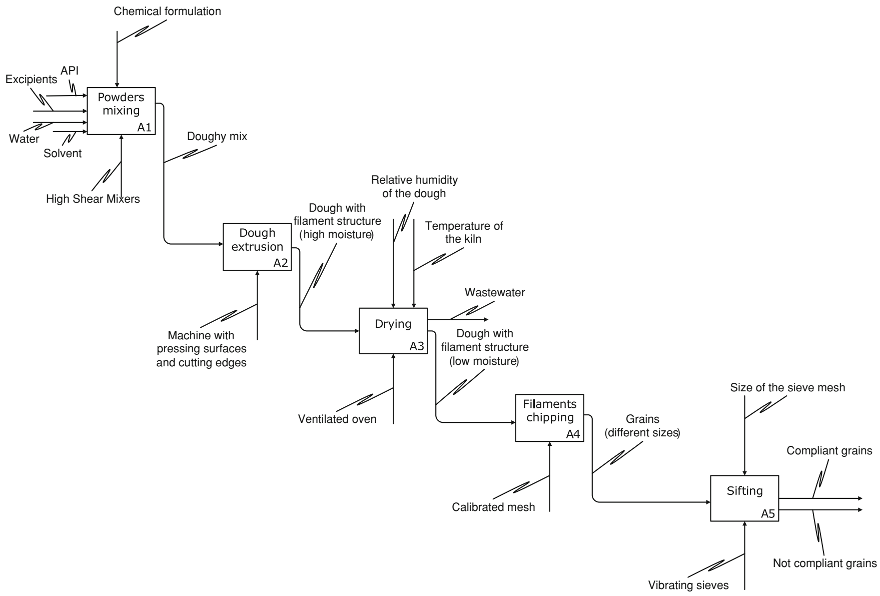

Fig. 3.1 Exemplary application of IDEF0 to model a pharmaceutical manufacturing process

IDEF0 is used to represent the constituent activities of the process and the conversion of inputs into outputs, in addition to the controls governing the transformation and the technologies required for performing the process. By employing the IDEF0 model, a preliminary schematization of the industrial activities and operations leading to the delivery of the product is viable to segment the business process into the phases to be subsequently analyzed. Indeed, coherently with the IDEF0, the business process is favorably represented within IPPR as a technical system constituted by chains of operations, whereas each box represents a phase. An exemplary application of the IDEF0 framework, with reference to an established manufacturing practice adopted in the pharmaceutical industry, is illustrated in Fig. 3.1, with the aim of showing the capabilities of the model to segment the process into the constituent phases.

The logic of the EMS model is exploited in order to consider also the flows of energy and signal/information among the involved resources. Suitable conventions can be adopted to remark such kinds of flows, as showed in Fig. 3.2, whereas the basic IDEF0 scheme for each single phase is enriched by the pertinent mapped features.

Eventually, the customized IPPR model is integrated with the highlighting of the monetary flows involved in the business process. The task requires therefore the indication of the expenditures involved within the system, to be favorably monitored throughout the terms that contribute to determine the Inventory and the Operating Expense, according to TOC model. In such a way, each activity can be characterized not only in terms of the parameters related to the technical domain, but also with different factors that participate to the generation of the costs to be

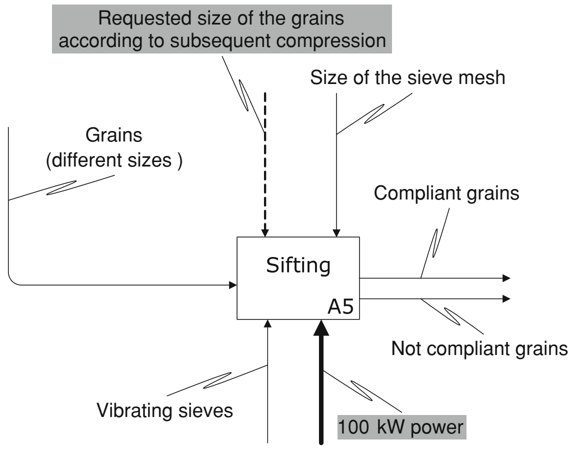

Fig. 3.2 The EMS model within the multi-domain model is adopted to represent the flows of energy, material and signal/information

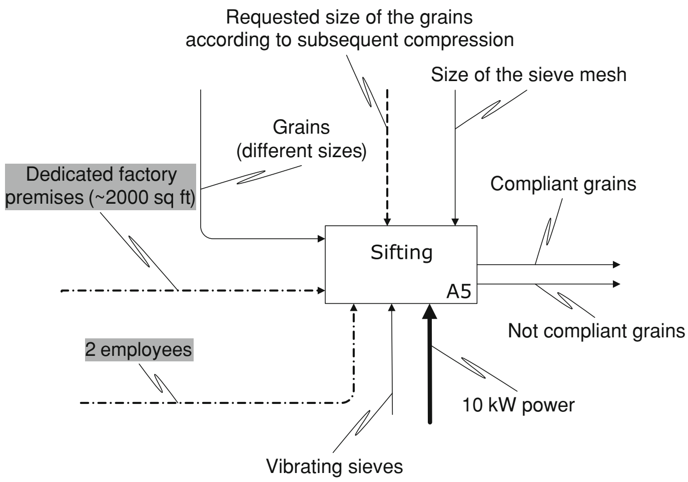

Fig. 3.3 Issues of the TOC model are employed to represent the flows of expenditures involved in the process

quantified for each phase: consumption and maintenance of the tools, labor, investments, expenditures for the plant or the offices, etc. The channeled resources, not previously mapped, that are due to Inventory and Operating Expenses, can be represented in the model through suitable conventions, as illustrated in Fig. 3.3, optionally indicating the amount of generated expenses.

As showed in Fig. 3.4, the model adopted for the purpose of IPPR requires to introduce the time needed to perform each phase, which is disregarded by the

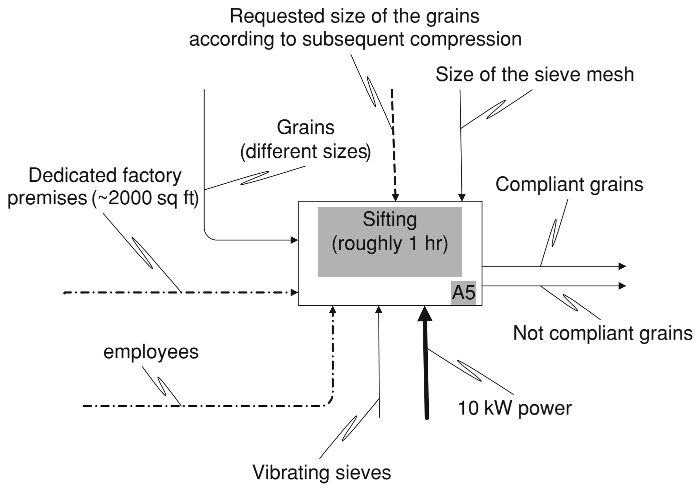

Fig. 3.4 Also the elapsed time of each activity is taken into consideration and represented in the model

previous techniques. The latter represents a relevant issue, especially when the competition is significantly based on the time to market.

Finally, the undesired effects that emerge from the display of the process activities are not to be neglected.

An enhanced formalism can be employed in order to discriminate when a flow or an action should be considered positive or harmful. Each elementary phase of the model is characterized by a function (or commonly a plurality of functions) involving a function carrier, an action and an object receiving the function and undergoing the modification of some of its features. The action is properly defined if it can be expressed through one among four verbs (increase, decrease, change, stabilize) and the name of the impacted property of the object, as suggested by the Element-Name-Value (ENV) model detailed in [1]. Such property (e.g. the length, the color, the electrical conductivity, the shape), is thus set to a certain value (e.g. one meter, red, five Siemens per meter, spherical), according to the extent of the function. As a consequence, the nature of the action (positive or negative) depends on the desirability of the occurred modifications of the property.

Diffusedly, unwanted phenomena associated with the phases result in additional expenditures for the firm in the form of introduced auxiliary operations (e.g. activation of security devices, employment of noise or emissions abatement equipment, machinery cleaning).

Thus, the overall consideration of involved resources has to include the undesired effects, currently beyond all remedy, and the auxiliary functions aimed at removing or mitigating the bad consequences of unwanted phenomena. Appropriate formalisms, as those proposed in Fig. 3.5, can be employed to describe such phenomena.

According to the description performed so far, the conventions adopted to build the Multi-domain process model are summarized in Fig. 3.6. Eventually, Fig. 3.7 depicts

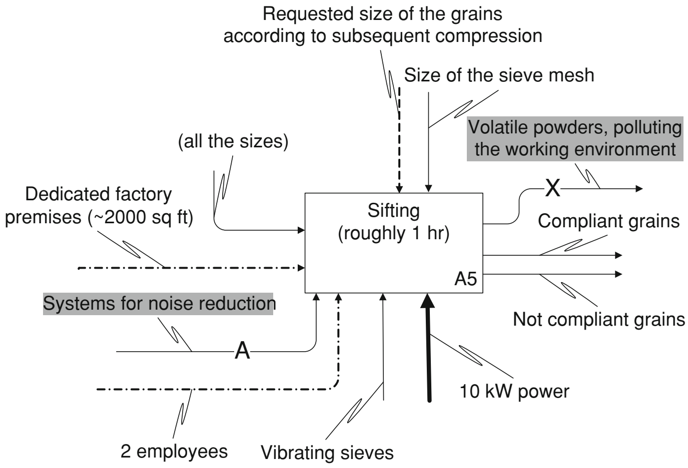

Fig. 3.5 The multi-domain model adopted by IPPR considers also the harmful or undesired flows involved in the phases, as well as the auxiliary functions needed to eliminate or mitigate unwanted phenomena

an example of graphical representation of a process phase according to the Multi-domain model.

The user is however free to adopt other graphical representations, techniques or models. Nevertheless, in order to perform the subsequent tasks, the process has to be structured by a list of industrial phases. For each of them the following information has to be gathered:

- inputs and outputs of materials;
- the energy and information channeled;
- the technologies to be adopted, the space occupied;
- the labor and personnel employed to perform, control and design the foreseen functions;
- the costs accounted in order to acquire or purchase the previously listed resources, as well as the financial investments necessary for the space occupied within the plant or the building;
- the elapsed time;
- drawbacks, undesired effects, auxiliary functions to face unwanted phenomena.

3.2.2 Tools for Product Information Elicitation

The application of IPPR to the reengineering problems of the classes 1 and 2 requires the identification of the value elements characterizing the product, expressed in the form of customer requirements. On the other hand, the fulfillment of a NVP task through IPPR, which is the activity performed to solve the

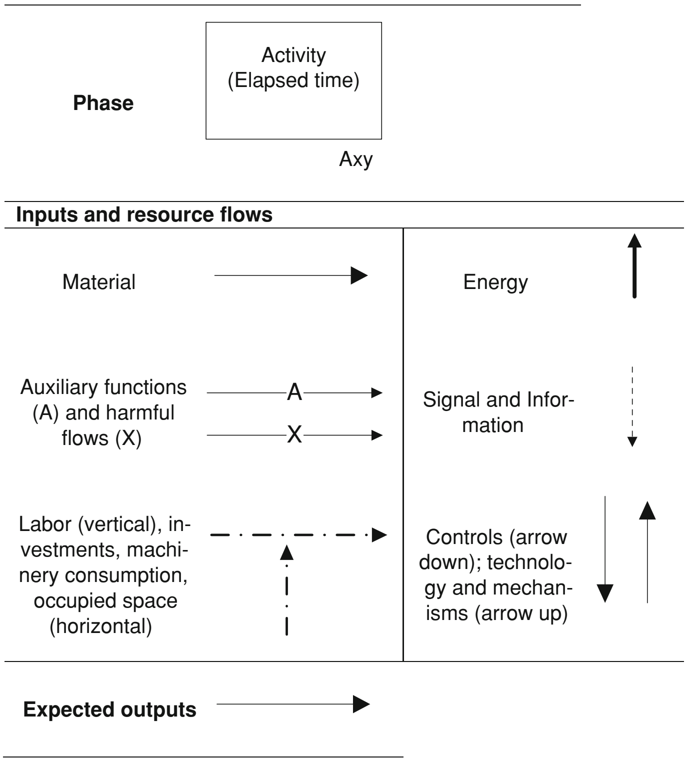

Fig. 3.6 The formalisms adopted to build the multi-domain model of the industrial process

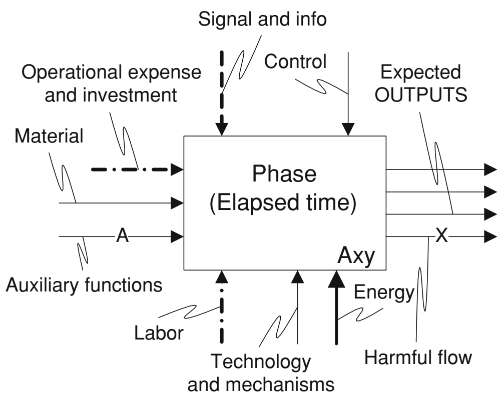

Fig. 3.7 Example of phase modeling according to the multi-domain technique

reengineering problems falling into class 3, needs the preliminary determination of the value elements offered by the as-is product, expressed in terms of value attributes. Thus, the investigation of the value elements held by the product/service constitutes a common task whatever the reengineering problem is. However, we have to highlight the following distinction:

- within the class 1, the customer requirements to be appointed are primarily (but not uniquely) those to be fulfilled within the process to be reengineered, as a result of underperformances or turbulences in the marketplace or in the boundary conditions;
- within the class 2, the customer requirements to be monitored are those delivered by the business process, as a result of the display of its phases;
- within the class 3, it is useful to map all the situations and circumstances influencing the employment of the product, its behavior, the drawbacks emerging as a result of its use or ownership. Thus the information to be collected and structured includes not only the explicit attributes, but also the complete experience generated along the product lifecycle, highlighting considered and unexploited sources of value and thus further business opportunities.

Then, whereas in the process reengineering tasks the customer requirements to be analyzed emerge as a result of the fulfillment of the phases, the mapping of the product attributes within the third class of business problems is advantageously enriched by the representation of the user experience, highlighting pros and cons.

This part of the Chapter offers the description of the tools suggested by IPPR to support the collection of data related to the industrial process and its outputs, i.e. *CRs checklist* (Sect. 3.2.2.1). Additionally, *Lifecycle System Operator* provides an useful aid to individuate the attributes of the product and the sources of value for the customer (Sect. 3.2.2.2).

3.2.2.1 Product Information Elicitation for Classes of Problems #1 and #2: CRs Checklist and Correlation Coefficients

The purpose of this activity is to determine a comprehensive list of customer requirements that participate to the generation of value and to measure the extent at which the process phases combine to bring about the fulfillment of the identified product attributes.

In order to consider the value aspects of the process outputs, a distinction can be made between processes operating in Business to Customer (B2C) or Business to Business (B2B) industries. In the first case the requirements to be satisfied concern the elements of value that can be appreciated by the mass of customers or a particular segment of end users. In the second case, the attributes to be taken into account regard both:

- the dimension of the industrial level of the direct customer, thus features such as the volume and the assortment of manufactured batches or additional services (e.g. transportation, certification, accomplishment of bureaucracies);
- the dimension of the quality aspects that result relevant downstream the supply chain, including the end user, which are enabled by a correct display of the analyzed business process; for example, a firm that processes raw copper and

manufactures wires has to fulfill certain requirements of the semi-finished products (size, flexibility, strength, etc.), which will allow an assembly industry to produce compliant electrical cables, further on appreciated by the end users.

It is worth to highlight that the elicitation of customer requirements can be carried out by considering different detail levels, leading to very diverging records of product attributes characterizing the outputs of the process. The same phenomenon regards the determination of the process phases. According to the authors' experience, in order to carry out equivalent analyses of the process and the product, it is recommended to use quantities of customer requirements and phases, whose ratio ranges from one half to two. Whereas such condition is not met, it is suggested to group the more numerous items within more general categories or to further segment the less abundant items (CRs or process phases).

In order to strengthen the elicitation of the attributes, IPPR proposes a tool, aiming at creating an exhaustive list of customer requirements. The proposed technique, namely *CRs checklist*, is a record of hints tailored to elicit the widest diffused kinds of product attributes. The newly individuated requirements are therefore to be grouped together with those extracted through the process analysis. CRs checklist recommends to consider a wider amount of issues, in order to identify further performances currently delivered to customers and stakeholders concerning the product and/or the offered batch of products, as suggested in [2]. The aspects to be considered are listed according to the *functional features* classification criteria, as follows:

- the useful functions (UF attributes), meant as the direct benefits perceived by the end user as a result of the product employment and more specifically:
  - the advantages arising from the exploitation of the product, which can be referred to the quality and the quantity of the desired output;
  - the amount of users for whom such benefits are met, thus the flexibility of the product according to different customer demands;
  - the capability of the product to meet the customer needs within the requested time;
  - the adaptability of the product when working in diverging conditions with respect to the designed preferred ones;
  - the stability of the product performances when subjected to external perturbations;
  - the chance to effectively control the system in order to obtain the expected outcomes;
  - the possibility to expand or upgrade the range of product functioning;
  - the opportunity provided to advantageously employ the product for not standard users or disabled people;
  - the possibility to customize the product or certain properties according to the user tastes and tendencies;
  - the possibility to use the system for different employments after the termination of main product functioning, the collection of matching items;

  - the aesthetical requirements and the emotional dimension of the product, the style, the fashion content, what it evokes in the user, the lifestyle that the object implies, the prestige it generates for the owner as a feeling of distinction and recognition;
  - the fun and adventure resulting from the use of the system;

- the strategies aiming at eliminating or attenuating the undesired effects (HF attributes), commonly associated with the product working:

  - the integrity of the product itself, its resistance to planned or accidental stress or collisions, the strength against wear or corrosion;
  - the limitation of damages towards treated objects or neighboring systems;
  - the environmental sustainability, the recyclability, the possibility to reuse the system or its parts reducing the amount of waste;
  - the ethics of the product as a distinguishing factor;
  - the safety and innocuousness for human health and people's psychological and social conditions;
  - the absence of bother for the user employing the product or for surrounding people, the comfort of use, the ergonomics, the manageability;
  - the reliability, the limited frequency of system failures;
  - the duration, the expected life of the product;

- the properties leading to the attenuation of the resources to be channeled by the buyer or the end-user of the system (RES attributes) and more specifically:

  - the limitation of occupied space, the lessening of the encumbrance, the accessibility, meant as a shrunk quantity of space required to allow the users to employ, store, transport, maintain and dismantle the product;
  - the working speed, the reduction of time to be waited before the functioning of the product delivers the expected outcomes, including the duration of the period to be waited before physically benefiting of the bought item or service after the purchase;
  - the limitation of the time required to maintain or fix the product, to change accessories, to dismantle the system, to learn how to use it, to administer or to accomplish the involved bureaucracies;
  - the reduction of the information and skills to be gathered in order to correctly use and control the product, the ease of employment, the user friendliness, the limitation of required training;
  - the ease of acquiring the product, due to market penetration and distribution policies;
  - the ease of managing, maintaining, assembling, disassembling, upgrading, substituting components or accessories;
  - the ease of choosing and individuating the product in the marketplace, according to recognizable features, due to technical, aesthetical or communication issues;
  - the lightness and the portability;

– the independence from the use of different materials, instruments, technical systems;
– the absence or limitation of the consumption of consumable items or materials;
– the reduction of auxiliary functions to be delivered in order to use, install, dismount or dispose the system;
– the limitation of the required energy needed for the product working, maintaining, installing, disposing, recycling; its efficiency;
– the decrease of the human power needed to use or transport the product;
– the additional services provided in order to attenuate the consumption of individual resources, as those listed in the previous bullets, the customer care.

The fact that the cost of the product for the user is not considered as a customer requirement, should not amaze, since, for the first two IPPR classes, it represents a direct consequence of the business process, the employment of the resources along its phases, as well as the pricing policies of the company.

As anticipated in Chap. 2, the process model eases the individuation of the main product performances that are intended to be fulfilled, by examining how the phases transform the inputs into the outputs. The strategy of exploring the performed process schematization can be used complementarily or in alternative to the employment of the CRs checklist. The model of the business process aids the elicitation of the customer requirements, by addressing for each process segment the question: "within the perspective of value delivery, which reason or scope motivates the transformation of the inputs into the outputs along the analyzed phase?". For example, if a process segment operates in order to modify the color of a certain object or material, IPPR users have to individuate the ultimate goal or the plurality of objectives to be achieved through the transformation. This leads therefore to determine the requirements to be fulfilled which are influenced by the color alteration, addressing to pertinent attributes, such as (according to the specific case) aesthetics, respect of norms, benefits concerning the heat transfer rate, intuitiveness of use, etc.

At the same time, the accomplishment of the customer requirements can be achieved by dealing with a set of parameters which are modified along the process display. Still by way of example, the designed style of a product, complying with the aesthetical requirements, can be attained by modifying both the color and the shape of an object. In simpler situations the fulfillment of customer requirements arises as a consequence of the modification or stabilization of a single parameter. In these cases there is a complete equivalence between the technical feature to be set and the customer requirement. Therefore, the distinction between an engineering characteristic and the met product attribute loses its meaning within the scope of IPPR.

Further on, the transformation of each parameter can be governed by one or more industrial activities, e.g. the correct dimension of the grains constituted by a pharmaceutical mixture is achieved by extruding and chipping the material, as suggested in Fig. 3.1.

In the context of product development, QFD [3] entails the identification of customer expectations and the rate at which engineering characteristics contribute to meet these needs. With a similar approach, in the scope of IPPR, the proposed procedure requires mapping the phases underlying the accomplishment of each CR and eventually evaluating the extent at which they participate to its fulfillment. Such contributions are designated with the name *correlation coefficients*. The book indicates each of these indexes with k_{ij}, meaning the relative contributions addressed to the j-th phase (within the record of process segments emerging from the process modeling) in ensuring the achievement of the i-th CR (according to the list of attributes resulting from the product investigation).

As a result of the concurrence of the (hypothetical) plurality of both modified parameters and industrial operations involved in the requirements fulfillment, the transformation chain implies that the attainment of each product attribute can result as the combined effect of more phases. In other terms, each process phase can contribute totally, partially or in no way to the delivery of satisfaction according to a specific customer requirement. The value assumed by the correlation coefficients, ranges therefore from 0 to 1; in each case the summation of the k_{ij} terms with respect to the list of phases has to be 1, as follows:

$$\sum_j k_{ij} = 1$$

It is worth to notice that each phase of the process model, if schematized according to the proposed framework, includes the parameters that govern and control the progress of the phases. The indicated issues favor the individuation of the mechanisms that lead to the accomplishment of the CRs, and thus the estimation of the correlation coefficients.

Further on, in order to correctly determine the k_{ij} indexes the analyzer has to take into account the extent of the transformations performed by the phases that lead towards the fulfillment of the CRs, as an immediate result (Fig. 3.8a) or by means of the accomplishment of engineering characteristics (Fig. 3.8b).

The recalled modifications that occur along the display of the process can regard both quantitative and qualitative parameters, to be expressed in terms of customer requirements or engineering features. In the first case the ratios measuring the influence on a parameter are fixed through a mathematical calculation, by considering how much the phase modifies that property with respect to the overall transformation that happens in the whole process. Otherwise, when dealing with qualitative aspects, the determination of the rates has to be carried out through estimations provided by sector experts. The same mechanism involves the measure of the impact of the engineering characteristics on the product attributes.

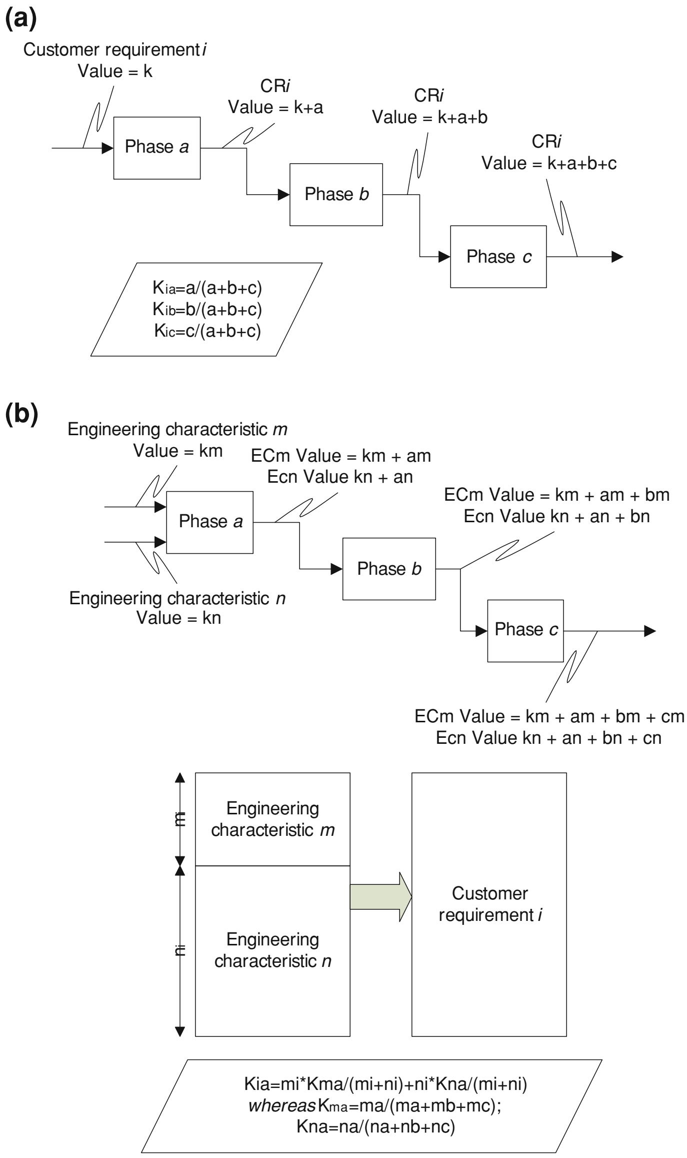

Fig. 3.8 Rules for the determination of the coefficients correlating the phases to the customer requirements. In **a** is shown the case in which the phases lead towards the fulfillment of the CRs, as an immediate result. While in **b** the case is presented where the CRs are obtained by the means of the accomplishment of engineering characteristics

3.2.2.2 Product Information Elicitation for Class of Problems #3: Lifecycle System Operator

With the aim of taking into account all the aspects that participate to the delivery of the value for the customer, the analysis has to be carried out by considering the following elements:

- *the life cycle*: by remarking any circumstance that may occur along the different stages of the existence of the product;
- *different levels of detail*: in order to pinpoint the potential benefits for the customer, that are likely to emerge by appropriately design the systems, at different hierarchical levels, that impact the product under investigation under various operating contexts.

Given its flexibility of use, the *System Operator*, as developed within TRIZ [4], can be employed as a powerful reasoning tool for mapping a wide range of situations, circumstances and working conditions otherwise neglected. In this context, a tailored version, namely *Lifecycle System Operator*, is used to elicit product attributes and individuate overlooked sources of value for the end-user. However, since the user can benefit of the original tool (beyond the customized one) in other contexts, he/she can find a comprehensive description of its objectives and characteristics in the Appendix D.

It is hereby proposed to adopt an appropriate subdivision of the temporal dimension of the product lifecycle, designed to pinpoint the most common situations in which the buyer can perceive value. Thus the time abscissa is considered starting from the moment the user begins to interact with the product. The lifecycle segmentation considers therefore the following phases:

- the purchasing, choice and access activities (e.g. ways of buying, determinants to select the product and its accessories, possibility to opt for a certain embodiment among different variants, negotiation for obtaining a service, fidelity bonds with the seller, trust in a trademark, awareness of the quality of the bought item);
- the operations and conditions preceding the employment of the system (e.g. mounting of an object, need of training, installation, suitable preparation of auxiliary systems, acquisition of documents, certificates or licenses);
- the utilization time, i.e. revealed performances of the system not previously evaluated, whatever impacts its employment, whatever allows it to function, the immediate impact of the working of the product on the surroundings and on the environment;
- the elapsed period before (and between) further exploitations (e.g. setup for a new employments, modification of the settings, keeping and maintenance, acquisition of novel functions, replacement of consumable items), as well as the impact of a single or a plurality of utilizations (e.g. health consequences, performance shrinking due to obsolescence);
- the phases related to the definitive termination of the functions, the dismantling (e.g. environmental issues related to the product disposal, recyclability,

reusability, alternative employments, collection of old items, negotiation to obtain new products or services).

Instead, in order to support the search of value elements according to different levels of detail at which the analyzed system can be considered during its life, it is suggested to organize the product dimensions in three main areas:

- the environment in which the product is situated;
- product or service itself, the operative zone;
- parts, components and accessories.

In accordance with these criteria, the customized version of the System Operator is presented in the Table 3.2, while an exemplary application is illustrated in Table 3.3, indicating the sources of value for a computer mouse.

The investigation schema suggested by the Lifecycle System Operator compels the user to ask himself the following question:

Are there any circumstances occurring during the <life cycle phase> and concerning the <product dimension>, to be observed and treated, resulting as inputs for a valuable design of the product?

Thus, the Lifecycle System Operator can be employed as a collection of fifteen questions, which support the scope of systematically browsing the possible sources of value offered by the product.

Subsequently, the individuated sources of value have to be appropriately elaborated and interpreted in order to elicit product attributes. With the objective of expressing the benefits ascribable to the product design in terms of value attributes, the user has to characterize the competing factors as parameters, whose increase in the offering level results in enhanced customer satisfaction.

The paths leading to the definition of the attributes differ according to the way the value sources have been depicted within the Lifecycle System Operator. In some cases, the value sources already express the feature that should be mapped as a product attribute (e.g. *lightness* or *shock resistance* in the Table 3.3). In other circumstances, undesired conditions are mapped and they have to be uttered in such a fashion as to individuate the capability to limit the related inconveniences, drawbacks or resources channeling. For instance, with reference to Table 3.3, the *cleaning issues* can be appropriately expressed in terms of *ease of cleaning*, *quickness of cleaning*, *limited frequency of required cleanings*, *absence of the need to employ particular products to perform the cleaning*, *absence of the need to clean the mouse*, etc. Further on, the sources of value can be expressed in terms of main or additional useful functions: in these conditions, the analyzer has to point out the benefits that arise as a result of the display of the recalled functions (e.g. from *scroll-up* in Table 3.3 up to define the *capability to support the end-user in browsing the file*).

In any situation, the translation of the monitored value sources into customer requirements can be carried out through the following questions:

Table 3.2 Lifecycle system operator: a tailored tool for the investigation of the value elements

		Lifecycle dimension				
		Purchasing, choice and access activities	Before use operations	Utilization time	Elapsed time before further exploitations	End of the functioning
Product dimension	Environment in which the product is situated	•	•	•	•	•
	Product or service level	•	•	•	•	•
	Parts, components and accessories	•	•	•	•	•

Table 3.3 Lifecycle system operator adopted to overview the sources of value and competitive advantage for a computer mouse

		Lifecycle dimension				
		Purchasing, choice and access activities	Before use operations	Utilization time	Elapsed time before further exploitations	End of the functioning
Product dimension	Environment in which the product is situated	Availability of sellers (shops, stores, E-commerce, etc.)	Compatibility with different computer ports	Compatibility with operative systems	Maintenance and reparability issues	
				Energy consumption		
				Surface adaptability		
			Ease of installation	Possibility to regulate the wire length	Cleaning issues	
			Configuration speed	Absence of wire	Limitation of human damages (i.e. carpal tunnel syndrome)	
	Product or service level	Availability of shapes and colours	Supplied case for keeping the object	Manoeuvrability, ease of flowing	Possibility of rewinding wire	Alternative employments in event of failure (i.e. collecting)
		Cheapness				
		Design				
		Pointing functions (buttons, scroll-up, trackball, etc.)		Grip, stability (i.e. against turning upside-down)		
		Other functions (i.e. light, calculator)		Ergonomics, comfort of use		
		Lightness		Pointing precision		
		Overall environmental sustainability		Availability of touch surface for clicking	Ease of rewinding wire	
		Customization, originality		Shock resistance	Item durability	
		Mouse pad matching		Flexibility of use (i.e. maximum allowed distance from computer)	Battery duration	
		Accessories and matching stuff		Indications about expected duration margin	Reduced encumbrance	
				3D usability	Transportability	
	Parts, components and accessories	Technology preference (mechanical, optical, laser)	Possibility to nest components into each other or to conveniently arrange for storage	LED guidance	Ease of batteries replacement	Ease of disassembling
					Cheapness of replaced batteries	Components recyclability

- which objective(s) can be achieved when the product or the surrounding settings are designed to exploit the conditions emerging by considering the <value source> in order to positively impact on customer satisfaction?
- which property(ies), parameter(s) or performance(s), regardless it(they) is(are) currently fulfilled or not, is(are) meant to be introduced, incremented or stabilized in order to attain the <previously individuated objective(s)> or, however, to enhance the present situation?

An example is provided in the followings, by treating the value source *mouse pad matching*, still picked up from Table 3.3, and providing likely answers:

- Q: which objective(s) can be achieved when the product or the surrounding settings are designed to exploit the conditions emerging by considering the *mouse pad matching* in order to positively impact on customer satisfaction?
- A: *combination of the shape and the design of the mouse and the pad*
- Q: which property(ies), parameter(s) or performance(s), regardless it(they) is(are) currently fulfilled or not, is(are) meant to be introduced, incremented or stabilized in order to attain the *combination of the shape and the design of the mouse and the pad* or, however, to enhance the present situation?
- A: *overall aesthetics*, *fun*, *ease of making the mouse flow*, *ease of choosing an appropriate combined mouse pad*.

The so gathered sample of product attributes can be favorably integrated with any further neglected customer requirement. Additional features can be individuated throughout the *CRs checklist* and by considering not yet monitored costs, to be expressed in terms of the cheapness in performing the purchasing, the assistance, the maintenance or other services. For instance, by considering UF categories referable to the versatility of the product, an additional value attribute could be represented by the *possibility to be used by both right- and left-handed people*.

3.2.3 Product Modeling

The complete representation of the product as a collection of customer requirements does not include just the record of relevant attributes, but a further characterization, which depends on the kind of reengineering problem to be solved.

Within the class 1, any IPPR user has to indicate the importance of each single customer requirement within the value delivery. Such pointer is needed also for the second class, which however requires a twofold way of representation. For this kind of reengineering problems the distinction is performed between attributes capable to delight customers and basic requirements to avoid dissatisfaction. The employment of Kano model, reported in Appendix E, is recommended within the scope of IPPR. In order to carry out the above characterization of the attributes, the literature offers a wide coverage of applications that employ customer surveys for the determination of attributes relevance and role in the perspective of value

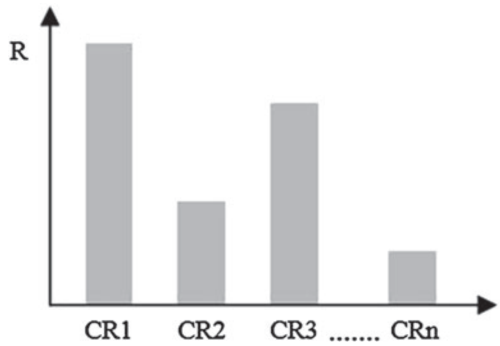

Fig. 3.9 The representation of the relevance indexes R for the set of customer requirements

delivery. Kano model itself has been developed as a customized strategy to extract and represent the Voice of the Customer. Along the time many alternatives have been proposed to indicate the most suitable CR accounted importance and Kano category, according to the outcomes of the surveys. IPPR users can employ any of the preferred models, by individuating the relevance indexes and distinguishing among Must-Be, One-Dimensional and Attractive features. However, such issues to be represented can be directly stated by business experts, whereas opinions of the clientele are unavailable or considered untrustworthy in the perspective of reengineering tasks, or the accomplishment of customer interviews is considered a too time-consuming task. The Sects. 3.2.3.1 and 3.2.3.2 provide a practical procedure to carry out the product modeling task, which is particularly suitable in event of the lack of customer surveyed opinions.

The classification of the product attributes for the scope of the third class is relevant in the perspective of the generation of a new product profile by the means of IPPR tools. The required characterization of the customer requirements in terms of functional features is described in the Sect. 3.2.3.3, which includes additional models to be further employed in order to ease the task of creating valuable profiles and choosing among alternatives.

3.2.3.1 Relevance Scale for the Classes 1 and 2

As previously recalled, the present activity deals with the determination of the extent (relevance index *R*) at which each customer requirement impacts the perceived satisfaction. Thus, the task is addressed at individuating, among the listed attributes, which features mostly impact the customer appreciation, motivate the choices among the products in the marketplace, result as a driver for promoting the buyer's loyalty.

Within IPPR it is suggested to express the relevance indexes with natural numbers through a Likert-type scale; in the performed IPPR implementations, including those presented in the Chaps. 4 and 5, the interval of scores for the R coefficients used to range from 1 to 5. By adopting this criterion the CRs characterized by a high relevance index relate to those competing factors playing a major influence within the customer experience when using the product. Conversely, the attributes characterized by low values of the R coefficient are assumed to be marginally relevant for the customer satisfaction.

Figure 3.9 reports a histogram which summarizes the extent of the importance indexes with reference to each customer requirement individuated in Sect. 3.2.2.1.

The notation R_i will be further on indicated to express the relevance of the generic i-th customer requirement.

3.2.3.2 Role of the Attributes Within Value Delivery for the Class 2

The hereby described task refers to the categorization of the customer requirements by considering their likely capability in providing unexpected value and/or guarding against strong discontentment. The logic of the classification to be performed follows the general idea of the Kano model, described with greater detail in the Appendix E. The introduction of different clusters for the product attributes is motivated by the need to individuate diversified directions of process reengineering with regards to the "kind of value" that is predominantly attained by the phases.

In order to establish the most suitable CR category, which describes the role in the determination of the perceived satisfaction, IPPR users has to answer the following questions for each listed product attribute:

- can the improper design and fulfillment of the <i-th CR> provoke customer dissatisfaction and rejection, since expected and demanded features are not met?
- can a correct accomplishment of the <i-th CR> combine to bring about customer appreciation, due to the generation of an unforeseen level of satisfaction from the buyer's viewpoint?

If just the first answer is affirmative, the investigated CR pertains the achievement of basic product characteristics and it can be classified within Must-Be (MB) attributes. If just the second reply is 'Yes' the related CR acts as a delighter for the consumer and has to be referred to Attractive (AT) competing factors. If both the answers are positive, the attainment of the analyzed CR results in the proportional delivery of perceived satisfaction according to the performance at which the attribute is provided, whereas low offering levels determine discontentment. Such requirements deal with the category of One-Dimensional (OD) competing factors. Eventually, if both the answers are 'No', the involved attribute does not provide any contribution in the product appreciation (Indifferent CR in the jargon of the Kano model) and it has to be crossed off from the list of relevant features. The logic of the attribution of the categories for the CRs is clarified through the Fig. 3.10.

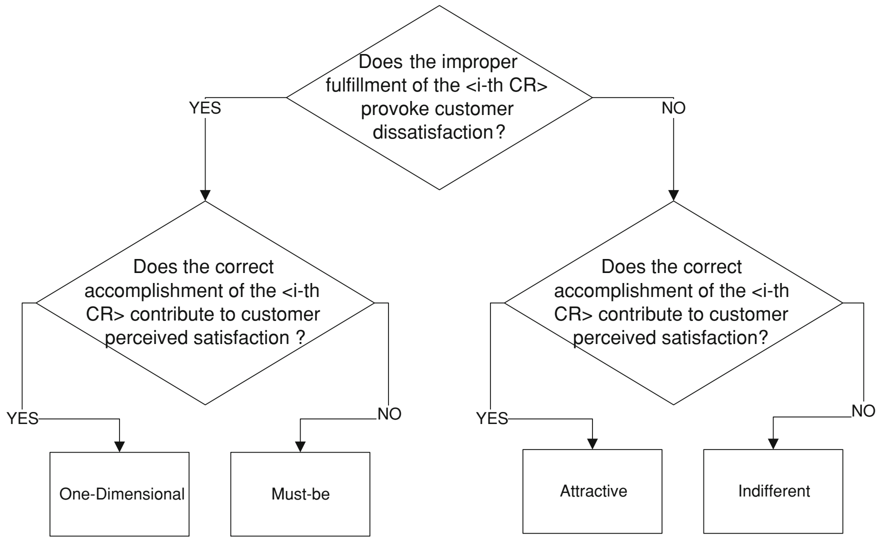

Fig. 3.10 Algorithm for the classification of the product attributes according to the Kano model

3.2.3.3 Categorization of the Attributes Through the Functional Features and Performance Evaluation for the Class 3

A step forward in the representation of the relevant product information for the third class of reengineering problems involves a twofold characterization of the collected attributes.

At first, a categorization has to be performed according to the clusters of *functional features* already illustrated in Sect. 3.2.2.1, by including the attributes pertaining the customer expenditures in the RES class. Each mapped customer requirement has to be therefore associated with the sound functional group, by considering from the buyer's viewpoint the benefits attained by the fulfillment of the attribute. If the task results complicated for the IPPR user, the following framework can result useful:

- if we consider the <product attribute>, are we dealing with the endeavor to request the customer less money, time, energy, space, tools, materials, information, experience or know-how? If the answer is YES, then the requirement can be addressed as a RES attribute. If the reply is NO, go to the following;
- if we consider the <product attribute>, are we dealing with the objective of reducing the impact of an undesired event, generally associated with the product functioning or decrementing the probability of such unwanted situation? If the answer is YES, then the requirement can be addressed as a HF attribute. If the reply is NO, go to the following;
- if we consider the <product attribute>, are we dealing with the effort of increasing the benefits for the customer or for a circumscribed group of users,

Table 3.4 Framework for summarizing the current product profile

Product attribute	Functional feature	Performance and customer demand
Lightness	RES	Good, outstripping the demand
Ease of cleaning	RES	Low, barely sufficient
Absence of the need to clean the mouse	HF	Absent, unsatisfying
Shock resistance	HF	Good, adequate
Capability to support the end-user in browsing the file	UF	Good, adequate
Overall aesthetics	UF	Moderate, barely sufficient

the versatility of the product functioning, the stability of the outcomes, the delight or happiness generated by the treated system? If the answer is YES, then the requirement can be addressed as a UF attribute. If the reply is NO, the attribute should be best deleted from the list in order to avoid subsequent bias.

In such a way the *lightness* and the *ease of cleaning* are, for instance, referred to RES attributes, since they work against a major involvement of the user individual resources and capabilities. Conversely, the *absence of the need to clean the mouse* and the *shock resistance* belong to the HF class, due to the intended scope of limiting the impact of undesired effects, such as the presence of dirty agents or any physical damage of the device. Eventually, the *capability to support the end-user in browsing the file* and the *overall aesthetics* fall into the cluster of UF customer requirements, since they are designed to directly give rise to benefits, accomplish requested tasks, arouse positive or playful emotions.

Finally, IPPR methodology requires the indication of the offering level that characterizes each product attribute, with a particular reference to customer exigencies, as arising by surveys or experts evaluations. Some features exactly meet the buyer expectations and needs, being the provided performance displayed at a degree capable to satisfy the customer, while higher levels would not result in increased contentment. In other cases, the desired performance degree of a certain attribute cannot be reached due to technological limitations or because of trade-offs with different conflicting demands. In further circumstances, the features result oversupplied, being their offering level greater than the actual requirements or expectations of the clientele. Generally speaking, the characterization of the offering level of the product attributes has to include both a qualitative level of the performance (e.g. absent, low, moderate, good, very high) and an evaluation about its relationship with the customer expectations (e.g. unsatisfying, barely sufficient, adequate, outstripping the demand).

Table 3.4 shows an exemplary classification of the previously cited product attributes pertaining a computer mouse.

It is worth to notice that the performance levels can strongly depend on different product configurations and variants. Hence, in case of treating products with fairly standardized value propositions, the presented scheme is sufficient to highlight the peculiarities of the marketplace. Conversely, if the distinction between two or more profile options is relevant within the aim of the reengineering initiative, the representation of the delivered product performance can be consolidated by employing the Value Curve (recalled in Chap. 1.3.2.3), a tool introduced within the Blue Ocean Strategy.

3.3 Implementation of the "Problem to Ideal Solution" Phase

This Section presents the instruments suggested by IPPR to perform the activities included in the Step 2 of the whole methodology. Depending on the reengineering problems, the main activities are:

- *class of problem* 1: identifying what should be changed in the process in order to overcome market boundaries;
- *class of problem* 2: identifying what should be changed in the process in order to recover competitiveness;
- *class of problem* 3: identifying what should be changed in the product in order to create a novel attracting profile.

Section 3.3.1 reports all the instruments required for the implementation of IPPR to address reengineering problems belonging to the class 1 and 2. Besides, Sect. 3.3.2 illustrates the tools needed to perform the NVP task which is expected to solve the reengineering problems of the class 3.

3.3.1 Performing the Identification of What Should be Changed in the Process

The instruments hereby presented support the execution of the activities involved in the identification of the process criticalities and the individuation of the most appropriate reengineering actions. These tools altogether allow:

- the determination of the *Phase Overall Satisfaction* index for the problems belonging to class 1 (Sect. 3.3.1.1);
- the calculation of the *Phase Overall Satisfaction* index for the problems belonging to class 2 (Sect. 3.3.1.2);
- the evaluation of the *Resources consumption* index for both the process oriented classes (Sect. 3.3.1.3);
- the assessment of the *Phase Overall Value* and the creation of the *PRAC* diagram for the classes 1 and 2 (Sect. 3.3.1.4);
- the determination of the *Value indexes* related to each process phase and the building of the *VAC* graph, pertaining the second class (Sect. 3.3.1.5).

The Phase Overall Satisfaction (POS) index represents a measure of the contribution that each process phase provides in determining the benefits perceived by the customer. The coefficient that assesses the Resources consumption is an overall measure of the investments and drawbacks faced by the company to carry out the process phases. The Overall Value (OV) index is viable to compare the benefits and the needed resources of each phase, thus elucidating which process segments are the most capable to generate satisfaction, according to the price paid by the company, and which ones result as bottlenecks in the same perspective. Further insights about the value delivery can be extracted throughout the diagrams named *POS versus RES Assessment Chart* (PRAC) and *Value Assessment Chart* (VAC), which characterize the nature of the criticalities, thus orientating the user towards suitable directions for process reengineering.

3.3.1.1 Measure of the Overall Satisfaction for Class 1

The schema adopted to evaluate the benefits for the customer, as they arise by the process, takes into account the impact of the phases in fulfilling the CRs, with a particular emphasis on the attributes characterized by a greater relevance. In this sense, the extent of the phases in the determination of the customer satisfaction is measured with regards to the combined effect of the contribution in delivering each requirement and the importance of the corresponding product feature in the perspective of value building.

As a result, the POS index for problems related to class 1 is calculated through the following expression:

$$POS_j = \sum_i k_{ij} \times R_i.$$

Thus, the esteem of provided satisfaction comes out by summing the shares of relevance indexes ascribable to the considered phase j.

3.3.1.2 Measure of the Overall Satisfaction and Other Indexes for Class 2

As illustrated in Sect. 3.2.3.2, the classification schema adopted by IPPR based on the Kano Model clusters the relevant customer requirements in three main categories that play a different role in the product perception: Must-Be, One-Dimensional and Attractive. On these bases, the class of problem 2 computes, for each CR, the terms expressing the capability to deliver customer satisfaction and indexes that measure the extent in avoiding discontentment. More specifically, as anticipated in Chap. 2:

- *Customer Satisfaction (CS)* represents the contribution given by an attribute to provide satisfaction with respect to the product or the service when the related CR is fulfilled;

Table 3.5 o_i, a_i and m_i coefficients according to the Kano classification of the i-th CR

	Must-Be	One-dimensional	Attractive
m_i	R_i	0	0
o_i	0	R_i	0
a_i	0	0	R_i

- *Customer Dissatisfaction (CD)* indicates the extent of the risks occurring when a given attribute of the product or the service is not met.

The above terms are calculated through expressions borrowed by literature contributions aiming at developing Kano model and extending its scope [5, 6]. In such a way, the *CS* and *CD* coefficients are calculated through the following expressions:

$$CS_i = \frac{o_i + a_i}{A + O + M};\; CD_i = -\frac{m_i + o_i}{A + O + M};$$

where:

- CS_i and CD_i are respectively the Customer Satisfaction and Dissatisfaction indexes for the i-th CR;
- A, O and M are the sums of the relevance indexes of Attractive, One-Dimensional and Must-Be CRs along the whole record of product attributes; thus the following formulas apply:

$$A = \sum a_i;\; O = \sum o_i;\; M = \sum m_i$$

- o_i, a_i and m_i are equal to 0 or correspond to the relevance degrees of i-th CR depending on whether it is classified as One-Dimensional, Attractive or Must-Be, as summarized in the Table 3.5.

The previously calculated indexes CS and CD, referring to each relevant product feature, allow to compute the *Phase Customer Satisfaction* (PCS) and the *Phase Customer Dissatisfaction* (PCD) coefficients, which represent the contributions of the phase in determining unexpected appreciation and avoiding discontentment.

PCS and PCD are determined through the following relationships, which take into consideration the correlation coefficients and the extents of the requirements in producing unspoken benefits and guarding from dissatisfaction:

$$PCS_j = \sum_i k_{ij} \times CS_i;\; PCD_j = \sum_i k_{ij} \times CD_i.$$

As discussed in Chap. 2, the POS is assessed, within reengineering problems of the second class, through an empirical function [7] which combines into a non-linear expression satisfaction and dissatisfaction coefficients. As a result, the POS is calculated through the formula:

$$POS_j = 0.29 \times PCS_j - 0.04 \times PCS_j^2 - 0.72 \times PCD_j + 0.07 \times PCD_j^2.$$

3.3.1.3 Resources Consumption for Classes 1 and 2

The business process has to be characterized also through coefficients that measure the degree of the impact played by undesired issues which, in the company perspective, are associated with the display of the phases. As represented in the process model, the whole range of disadvantages is constituted by elapsed times, harmful phenomena and costs, determined by a wide variety of resources to be channeled and auxiliary operations that allow the execution of the phases. The *Resources consumption* index is aimed at quantifying the extent of such inconveniences occurring during each process phase. The coefficient is evaluated through the following formula:

$$RES_j = c \times C_j + t \times T_j + h \times HF_j$$

where:

- C_j represents the share of the total costs incurred to carry out the j-th phase (materials, energy investments, auxiliary functions, labor, space, machinery, etc.);
- T_j indicates the share of time spent in completing the j-th phase, with reference to the whole business process;
- HF_j is the share of the estimated damage produced by harmful effects arising from the j-th phase;
- c, t and h stand for coefficients, determined by business process experts, expressing the relevance of expenditures, elapsed times and drawbacks in hindering the market access (1st class of problems) or the preservation of the competitiveness (2nd class of problems).

The employment of shares instead of real values is dictated by the need to sum parameters with different units of measurement. The introduction of the lastly mentioned coefficients is proposed to take into account different situations, e.g. c is predominant when the business process is associated with a very poor profit, t grows when the time to market is a relevant competing factor, h assumes considerable values when the undesired aspects produce great drawbacks for the life and the image of the company.

In order to better compare the Resources consumption extents of the various phases, it is suggested to determine the normalized values of these coefficients. In this way the phases can be characterized by their accounted relevance in generating demands and undesired effects for the business process.

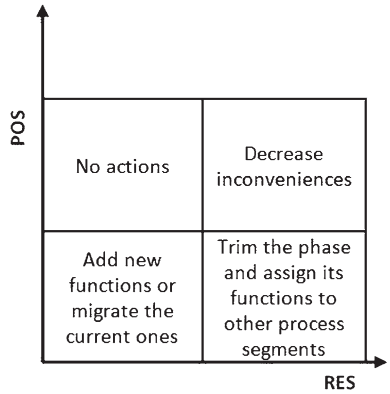

Fig. 3.11 The POS–RES assessment chart. The positioning of the process phases according to the POS and RES indexes, facilitates the identification of the process criticalities and of the subsequent reengineering actions

3.3.1.4 Overall Value and PRAC Diagram for Classes 1 and 2

The ratio between the general amount of benefits and the extent of disadvantages heads to the determination of the *Overall Value* (OV) coefficient. Such index, if referred to the j-th phase of the process, is calculated through the following relationship:

$$OV_j = \frac{POS_j}{RES_j}.$$

The extents of the OV parameters pertaining each phase can be advantageously normalized in order to express the global value of the process segments through percentage scores.

The OV indicator is suitable to identify, at a first evaluation level, strengths and weaknesses of the business process with reference to the set of phases. According to this metric, the phases showing a high OV rate can be considered to be tailored to the business process and their employed resources are well spent in generating customer satisfaction. Conversely, the process segments with low OV scores represent problematic issues and bottlenecks in the value creation process.

The separate consideration of POS and RES indexes is viable to highlight the nature of the bottleneck, by referring, more specifically, to a poor participation to value generation and/or to an excessive amount of expenditures and inconveniences. The above coefficients are employed to build the *POS versus RES Assessment Chart* (PRAC) (Fig. 3.11), which positions the phases in a diagram capable to illustrate the overall situation of the process with regards to the spent resources and the amount of benefits generated for the customer. Such diagram is thus capable to summarize relevant process aspects in terms of both the quality of the outputs and the internal demands through the introduction of ad-hoc metrics pertaining the performed business phases. In other words, the PRAC facilitates the analysis of the process criticalities by splitting the focus on the numerator of and on the denominator of the ratio expressing the OV.

According to the position assumed by each phase in the chart, it is possible to identify the most suitable directions for the business reengineering initiative, by aiming at removing the process shortcomings and bottlenecks. The redesign actions to be pursued depend on the order of magnitude of the POS and RES indexes and more in detail on the distinction between low and high values for the same coefficients. By using a practical criterion an index is conceived as low when its value is smaller than the mean assumed by the sample of phases (and high, obviously, in the opposite case). Alternatively, whereas the record of investigated phases is particularly rich (indicatively, more than 15 items), the low coefficients can be considered those whose values range in the first quadrant if the overall set of quantities is considered. The emerging decision support for BPR task is articulated as follows with reference to the values assumed by POS and RES:

- *Low POS and high RES*: the scarce performances of the phase are related to both a considerable consumption of resources and a low contribution in determining the customer satisfaction. The reengineering task should evaluate the opportunity to eliminate the phase by assigning its delivered benefits to another segment of the process.
- *Low POS and low RES*: the poor OV rate of the phase is due to a limited contribution to the customer satisfaction. The reengineering actions to be undertaken should be oriented towards assigning the treated phase new functions to be delivered without a meaningful increase of the needed resources. As an alternative, given the poor benefits, it could be evaluated whether it is possible to integrate the currently performed functions within the display of other phases.
- *High POS and High RES*: in case the phase assumes a low OV rate, this has to be ascribed to a high denominator, i.e. high expenses or drawbacks. The focus of the reengineering initiative should be addressed towards a reduction of the main cost factors. In this sense chance is constituted by the substitution of the technology adopted so far.
- *High POS and low RES*: in such a case the phase plays a relevant role in determining the customer contentment and it the employs a low amount of resources, thus it should not be subjected to any reengineering action.

3.3.1.5 Phases Value and VAC Diagram for Class 2

In addition to the OV index, other metrics can be likewise introduced to point out the relationship between provided benefits and spent resources. The task should be carried out by resorting to the coefficients PCS and PCD, which have been introduced in the Sect. 3.3.1.2, giving rise to the *Value for Exciting requirements* (VE_j) and the *Value for Needed requirements* (VN_j). The last parameters represent the suitability of the resources employed along the phases in achieving customer satisfaction through unexpected properties of the product (VE_j) and in fulfilling the basic requirements so to avoid strong consumer discontent (VN_j). They are calculated through the following formulas:

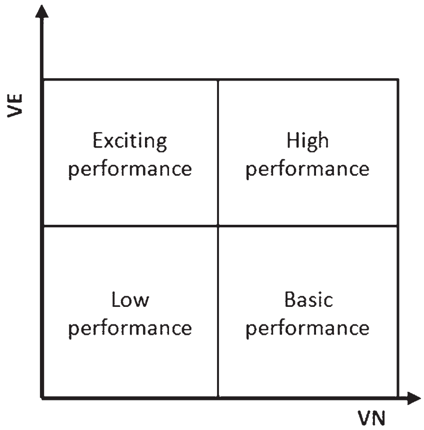

Fig. 3.12 The value assessment chart. It allows the clustering of the process phases in four main areas which are related to the performances in determining the customer satisfaction and in avoiding the dissatisfaction

$$VE_j = \frac{PCS_j}{RES_j};\ VN_j = \left|\frac{PCD_j}{RES_j}\right|.$$

In order to enhance the usability of the terms by employing more meaningful values, the VE and VN coefficients can be advantageously transformed into normalized extents or relative percentages.

A more intuitive analysis can be performed by considering the *Value Assessment Chart* (VAC) which is a useful representation of the phases according to the VE and VN indexes (Fig. 3.12). The values of VE and VN are considered low or high with the same criteria illustrated in Sect. 3.3.1.4.

As well as the PRAC, the VAC highlights the process criticalities and it leads towards the determination of the most appropriate reengineering directions for the removal of value bottlenecks. However the VAC adopts a different perspective than the first diagram, by focusing on whether the employed resources are well calibrated to guarantee the customer satisfaction and/or avoid dissatisfaction. The VAC graph can be used conjointly with the PRAC diagram or as an alternative for the decision support about the nature of the reengineering initiatives to be pursued.

According to VAC the process phases can be clustered in four main areas:

- *Low performance (low VN and low VE)*: the employed resources do not guarantee an adequate appreciation level of the product and they cannot avoid consumer dissatisfaction. The phases falling in this area thus need strong changes and also the opportunity of their elimination should be considered. It has to be investigated whether the low VE and VN rates depend on low benefits or high employed resources. A phase belonging to the former set is often worth to trim, by assigning the same minimal benefits to other existing phases. Besides, if the low value is due to high resources consumption, specific actions aimed at determining a leaner phase should be applied (indeed, this is the case when Lean Manufacturing provides maximum benefits). A further opportunity is to use the excess of resources for generating new attractive properties within the phase.

- *Basic performance (high VN and low VE)*: the employed resources do not provide unexpected benefits for the customer, but they are well spent to avoid consumer dissatisfaction. Typically, such phases are already optimized and oriented to fulfil the fundamental attributes; they do not need strong modifications and are not worth of consistent investments.
- *Exciting performance*: in this case, employed resources play an evident role to produce an adequate product appreciation level but they cannot avoid consumer dissatisfaction. Such phases are worth of investments in order to maximize their generated benefits; their success is a key to let the product to differ from the competitors.
- *High performance*: this quadrant is characterized by phases capable to provide well perceivable sometimes even unexpected benefits, still maintaining an extreme efficiency for fulfilling basic necessary needs. These phases are excellently tailored to the business process and they are worth to be safeguarded due do their high performances.

3.3.2 Performing the Identification of What Should be Changed in the Product

As inferable from Chap. 1.3.2.3, any reorganization of the product profile to be attained through a New Value Proposition (NVP) involves consistent modifications in terms of the value attributes offered to the customer and of their displayed performances. According to the scheme suggested by the Four Actions Framework (FAF, including Eliminate, Raise, Reduce, Create), the endeavor of a NVP task should be oriented towards introducing new competing factors and emphasizing those product attributes, whose offering level is still inadequate. Since such measures could go to the detriment of other valuable product aspects, it is recommended to miss out those customer requirements on which the market has long competed on or that result oversupplied.

By no way such ideal conditions can be encountered in any specific reengineering activity, technical field, industry or market. It can indeed happen that the customers of certain products, although in need of profound value redefinition, cannot give up (at least apparently) well established benefits. In different circumstances, showing a major need for the profile redesign, a big amount of alternatives can result viable on the basis of the indications provided throughout the FAF.

The tool that IPPR proposes for determination of an ideal product profile, still within the range of the solutions feasible at a first instance, fortifies the applicability of the Four Actions. The adopted framework, namely *New Value Proposition Guidelines* (NVPGs), supplements the mentioned reengineering actions with recommendations about which attributes to be subjected to the profile transformation process. The purpose of the suggested technique is to indicate what should be best

Table 3.6 Summary of the new value proposition guidelines

Most favorable actions	Actions to be maximally avoided
Create RES	Reduce RES
Create UF	Eliminate HF
Raise HF	
Raise RES	

done and should be avoided at a maximum extent, with regards to the functional features through which the product attributes have been classified. In other words, the guidelines remark which categories of competing factors are preferentially transformed within value transitions to be designed with respect to the Eliminate, Raise, Reduce, Create actions belonging to the FAF.

The NVPGs originate from an in-depth analysis of successful experiences, among which examples used as textbook cases for BOS, and stories of market flops, all concerning radical value transitions. The outcomes arise as a result of an initial part of the investigation, described in detail in [8, 9], and of further not yet published researches.

As a result of the way the guidelines have been extracted, they are structured as a collection of suggestions in terms of the functional typologies concerning the customer requirements to be involved in the transformation of the value profile. Hence, they individuate with major confidence the new valuable product attributes to be created, the existing properties to be enhanced, the current features whose performances are viable to be reduced and eventually the product characteristics to be eliminated without relevant drawbacks. The robustness of the arisen indications has been checked by the means of a χ^2 test, adopted to highlight whether the crossed distribution of actions and functional features could be due to chance.

The NVPGs, as resulting from the conducted survey, can be expressed as follows or, more schematically, through Table 3.6:

- *Create action*: considerable advantages arise by introducing neglected features, centered on the reduction of employed resources within the buyer perspective; a considerably positive role is played also by the emergence of novel functionalities or not previously considered characteristics impacting the user state of mind; the generation of new attributes aimed at facing unresolved troubles provides minor benefits;
- *Raise action*: it is observed that the meaningful mitigations of the inconveniences due to Harmful Functions (HF) and to the consumption of Resources (RES) are the most recommendable; a leap concerning the performance of the functional requirements results in less evident advantages;
- *Reduce action*: while the drop of the performances of the attributes classified as UF and HF (hence the deterioration of the impact due to undesired phenomena) is tolerated, major drawbacks are caused by a considerable increase in the resources employment;

- *Eliminate action*: whereas the NVP task can bear the elimination from the bundle of product attributes of features clustered with UF or RES (thus the need to employ kinds of resources not previously engaged), the emergence of unprecedented undesired effects maximally contributes to market failure.

The so determined guidelines are viable to support the process of generating innovative product profiles or business models, by considerably delimitating the space for alternatives within new value proposition tasks. However, the indications dictated by the suggested tool have to be maximally harmonized with the mentioned general criteria involving the employment of the FAF. In other words, the designed actions aimed at building a new value profile has to take into account, at the greatest extent, both:

- the functional features of the subjected attributes, by choosing the most advantageous measures, according to the NVPGs, or at least avoiding the patterns viable to generate the biggest harm;
- the market-related evaluations regarding the attributes, by introducing absent and besides promising aspects, by boosting the features supplied at an unsatisfying performance level and by dedicating less effort to fulfill the customer requirements which outstrip the demand or however kindle minor attention.

Thus, the ultimate goal is the application of the NVPGs without infringing the fundamentals, although fuzzily formulated, of the original FAF.

The individuation of suitable attributes to be involved in the implementation of value-adding actions (Create and Raise) follows the product mapping finalized in the first Step of the IPPR procedure for class 3 of problems (Sect. 3.2.3.3). The choice of the focus advantages to be pursued within the accomplishment of the NVP task results the prior activity in addressing the switchover towards the projected product profile. At this stage, the IPPR user defines the basic actions characterizing the value transition, striving to identify, given the known technology, preliminary conceptual solutions and one or more market segments, capable to represent the first adopters of the enhanced business. The planned beneficial attainments are favorably accomplished without resorting to negatively impacting actions, especially those specified in Table 3.6.

In order not to build an unrealistic value changeover, the definition of the NVP architecture has to alternate the fine-tuning of a comprehensive list of actions associated with the correlated attributes and cycles aimed at delineating, though approximately, a physical idea. The latter can be properly supported by the tools suggested in the Step 3 of IPPR: further details about the subject are provided in Sect. 3.4.2.

Within the scope of the present Section, IPPR advices on the roadmap to be followed for achieving a potentially successful value profile:

(1) identify the main directions for product reengineering in compliance with the value-adding actions (Raise, Create) foreseen by NVPGs and FAF, highlighting whether the attained benefits are likely to be perceived by the whole market or some niche;

(2) generate a preliminary, although fuzzy, conceptual idea about how the previous selected actions (accompanied by the attributes) could be implemented, avoiding sophisticated or front-end technologies;
(3) check out whether the basic idea for product development could involve value reducing actions (Reduce, Eliminate) infringing the FAF or potentially revealing serious inconveniences according to NVPGs; reformulate the basic idea at step (2), if the disadvantages result excessively severe;
(4) write down each newly introduced action, updating the list of measures attained by the present NVP;
(5) progress towards a clearer physical solution that exploits the so far generated sample of actions, attempting to avoid those action potentially leading to the failure of the NVP initiative;
(6) check out whether the new product configuration gives rise to novel actions, regardless they are meant to enhance or reduce the customer satisfaction; update the list;
(7) verify whether the number of value-adding actions is consistently greater than those determining disadvantages and if the presence of not-compliant measures is marginal; in positive case, adopt the performed NVP, otherwise enrich the delivery of benefits restarting from point (1) or improve the product embodiment, overcoming the current shortcomings iterating from step (5).

3.4 Implementation of the "Ideal Solution to Physical Solution" Phase

The last step of IPPR is related to the identification of suitable physical solutions for the implementation of the new process, if the reengineering effort is within the scope of the classes 1 or 2, or the design of a novel product concept in case of the belonging to the 3rd group of business problems. The purpose of the Section is to identify the most suitable well-acknowledged tools coping with the indications about reengineering actions to be undertaken, as emerged from the previous step.

According to this objective, Sect. 3.4.1 suggests possible instruments to design the new industrial process while, Sect. 3.4.2 gives an overview of the tools that can support the conceptual design of a new product idea.

3.4.1 Guidelines for the Selection of the Process Redesign Tools

Here in the followings, selection criteria are provided in order to individuate the suitable instruments to finalize the reengineering task. The suggested tools aim at supporting the user in the redesign of the industrial process according to the actions emerged from the IPPR analyses.

As widely described in the previous Section, the directions which arise from the *Problem to Ideal solution* step to attain the improvement of a process may be briefly summarized as:

- enhance the Overall Value of the phase;
- trim the phase and, in such an event, assign the function to another process segment.

If the increment of the Overall Value is addressed at the growth of the arisen benefits, the strategy to be followed concerns either the enhancement of the phase performances or the exploitation of its capabilities to provide new customer requirements. In this situation the user has to investigate physical solutions aimed at enhancing the potentialities of the available technology or identify new ways for the implementation of the same function. Among the several contributions available in the literature, the *Classes 1.1* and *2* of the *76 Standard Solutions* belonging to the TRIZ body of knowledge [4], represents a viable design tool to attain the proposed objectives.

When a phase to be reengineered shows a high resources consumption, the objective of improving the Overall Value rate can be accomplished by identifying solutions which result more efficient. If the speed to introduce the product in the marketplace, or the timeliness of the goods delivery, represent the most critical issues, the design of new scheduling layouts aimed at minimizing the operational times can be supported by *Quick Response Manufacturing* [10]. In different circumstances, emerging undesired effects can represent a significant concern for the display of the business process. In this case the rethinking of the phases constituting the process bottleneck should be addresses towards a solution that conciliates the delivery of the attained benefits without provoking the manifested drawbacks. In order to pursue a more ideal solution, rather than a tradeoff between the extent of useful and harmful outputs, TRIZ tools are recommended to overcome the contradiction between the emerging pros and cons. In this perspective, the Algorithm for Inventive Problem Solving (ARIZ) [4] represents the most appropriate instrument to be implemented. Whereas the level of monetary expenditures represents the most evident cause of the process criticalities, the channeling of the resources has to be reorganized with the greatest priority. The *Lean Manufacturing* [11] provides a set of instruments capable to guide the designer in the identification of the resources which can be saved by the process, since they poorly impact the value for the customer. The *Class 2* of the *76 Standard Solution* provides suitable directions for reorganizing the flow of the resources with a particular focus on those resulting underused and on the process wastes. More specifically such tool guides towards the employment of underexploited resources for sustaining new additional industrial operations capable to provide further benefits for the product buyer.

Eventually, the results of the analysis of the business process may suggest to attain improvements by trimming phases showing very low performances. In addition, such strategy requires the assignment of the performed functions to other phases of the process. The task therefore necessitates the identification of substitution

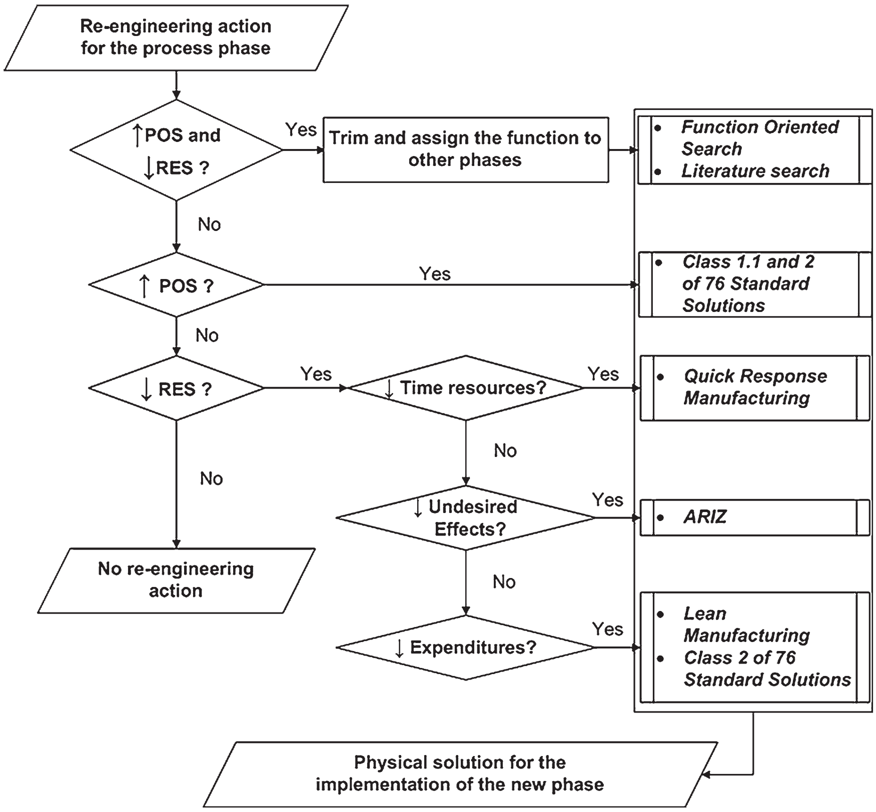

Fig. 3.13 Schema for the selection of the most suitable design tools according to the reengineering action to be implemented with reference to the results of the process analysis

technologies capable to satisfy the supplementary functional requirements without considerably impacting the resources consumption. To this end, a candidate support is represented by the *Function Oriented Search* approach [12], that allows to discover suitable technical solutions on the basis of the functional requirements to be fulfilled. An aid can be provided through the literature search: the consultation of scientific and technical databases, design catalogues and other sources of information has to be conducted with the aim of gathering sufficient knowledge for implementing a suitable technical solution. The proposed approaches involve the exploration of large amounts of data in order to extract the relevant information, thus the task can be eased by employing proper Knowledge Management systems.

Figure 3.13 depicts the selection path for the tools described so far, according to the kind of redesign action to be implemented for the phases to be reengineered, as arising from the observation of the PRAC and/or the low performance quadrant of the VAC diagram. In the latter case, with reference to the cells of the depicted flow chart highlighted in grey, the concurrent presence is excluded of sufficient delivered benefits and reduced resources consumption.

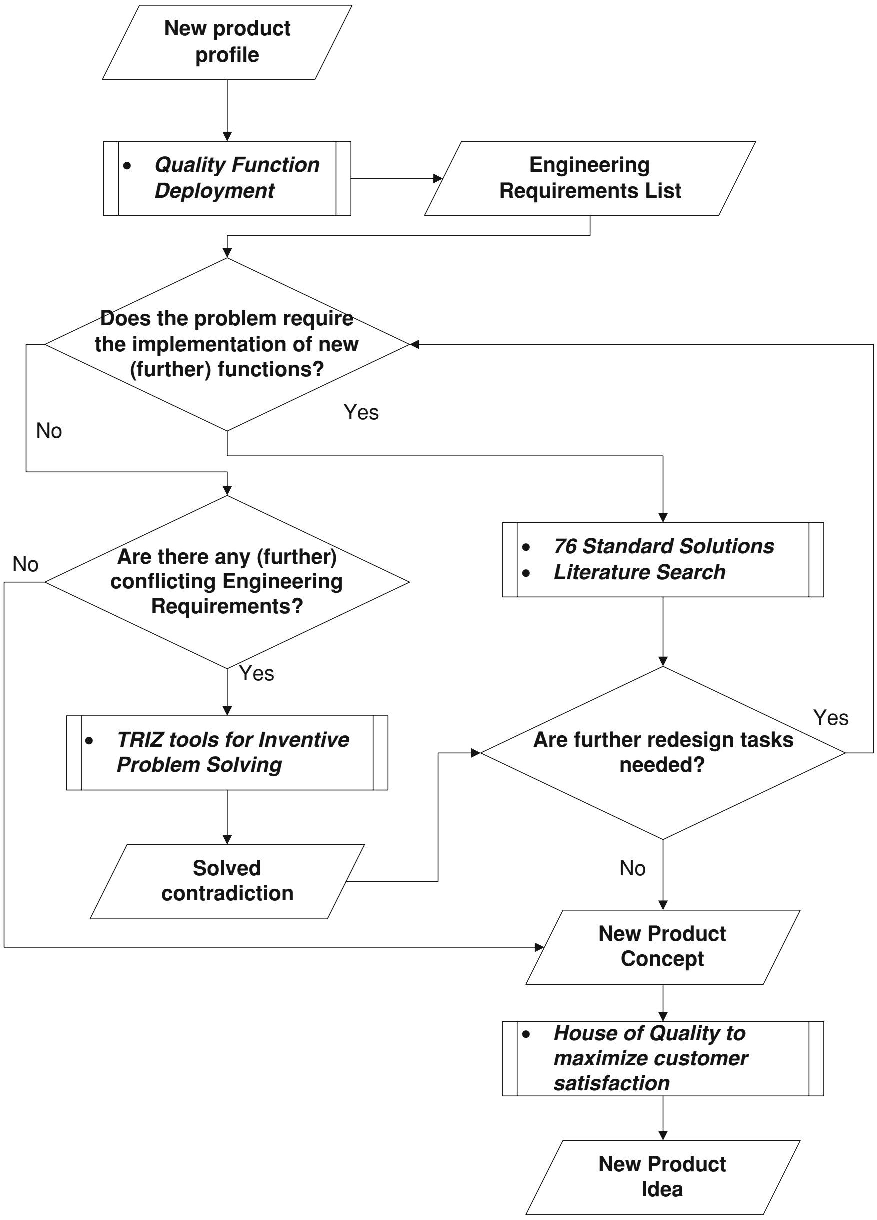

Fig. 3.14 Schema for the selection of the most suitable design tools to implement the hints emerging from the generation of an innovative product profile

3.4.2 Guidelines for the Selection of Product Redesign Tools

The output provided by IPPR with regards to the reengineering problems of class 3, consists in a set of new customer requirements to be translated into suitable product features. The identification of a new product idea capable to implement the innovative sample of product attributes at the required level of performances, refers to what the engineering literature acknowledges as a conceptual design task. Plenty of tools have been suggested to support the reengineering initiatives involved in the generation of new product concepts. Some valuable approaches are hereby suggested in order to orient the user towards the most effective tools according to the specific objectives of the design problem phase.

A preparative activity preceding the conceptualization of the technical solution is represented by the clarification of the design task. It consists in the translation of the customer requirements into well defined engineering characteristics. The detailed analysis of such features aims at identifying possible hurdles to fulfill the established product attributes. The output of this phase consists in a list summarizing the identified Engineering Requirements as well as a clear vision of the complexity of the design task. In such context, *Quality Function Deployment* (QFD) [3] is tailored to perform such preliminary design task. The model employed by QFD is capable to link each customer requirement to the related engineering characteristics, thus highlighting the most relevant technical performances to be fulfilled in order to maximally satisfy the customer. Moreover, the tool allows to remark the negative interactions among the engineering requirements, thus providing a clear vision of the conflicts which hinder the achievement of the required performances.

In some cases, the generation of the novel product concept may require the implementation of unprecedented functions; such task can be supported by the knowledge already available, which could however result insufficient. The *76 Standard Solution*s [4] or the literature search may be effective approaches which can guide the user towards the feasible technical solution. However, due to the variegated nature of the involved attributes within product profiles, the solution could require the knowledge dispersed across complementary disciplines (technology, management, market, computer science, human resources, etc.). Thus, the embodiment of an engineering solution may involve multidisciplinary competences, even external to the design team knowledge. This task can be suitably supported by Knowledge Management (KM) tools, in order to retrieve and use information from patents, scientific journals etc. even with limited resources.

In other circumstances the design problem is affected by incompatible extents of engineering requirements, meaning that a certain design choice allows the fulfillment of a given attribute, but results in disregarding other demands. Whereas one or more conflicts among the engineering characteristics come out, the design process requires to overcome these contradiction in order to generate a solution concept capable to conciliate the diverging requests. In such context, the tools provided by TRIZ to dig and solve technical contradictions represent an effectual aid to attain innovative ideas.

According to the above described criteria, Fig. 3.14 depicts a selection diagram supporting the identification of the most suitable tool according to the kind of design problem to be addressed. The flowchart terminates with the advised employment of the *House of Quality* [3] in order to set the relevant design parameters at such an extent to maximize the customer satisfaction. The task strengthens the definition of the physical solution implementing the innovative product profile.

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Chapter 4
Application of IPPR to the Reengineering Problems of Class 1

4.1 Introduction: The Italian Industry of Woody Bio-Fuel

In this Chapter the application of the methodology is presented to the woody pellet production process. This sector presents high business opportunities in Italy since the market demand of such kind of energy sources is grown dramatically in the last five years. Besides, the industrial processes treating widely available (but not optimal) resources are still under development. Their poor performance does not allow the attainment of an output complying with the requirements imposed by regulations and standards currently in force, if not resorting to heavy expenditures. Consequently, the business process is not able to fully exploit the available biomass resources, giving rise to the impossibility to meet the unsatisfied market demand of woody fuels.

In such context, the applicability of the developed approach to industrial problems originated by this kind of under capacities has been tested.

The content of the Chapter is structured in three main parts. Section 4.2 reports an overview of the faced problem, delving into its main critical aspects. The Sect. 4.3 presents the application of the IPPR methodology with the aim of showing how the suggested tools are employed. Eventually, Sect. 4.4 provides a brief discussion on the consistency of the obtained results.

4.2 General Overview of the Business Process

The solid bio-fuel coming from the sustainable exploitation of forest resources represents a not negligible complementary source of energy to oil and its derivatives. In the last years the market demand of such a resource is dramatically grown, with a particular reference to Italy, resulting in a business opportunity for several rural areas: one of these is the Tosco-Emiliano Apennine, a mountainous territory in the north-central part of the country.

F. Rotini et al., *Re-engineering of Products and Processes*,
Springer Series in Advanced Manufacturing, DOI: 10.1007/978-1-4471-4017-7_4,

Two different kinds of bio-fuel are obtained by the sustainable exploitation of the forest resources:

- *wood chips*: pieces of wood having overall dimensions of 25 × 30 × 20 mm, maximum moisture content of 20% in weight, average market price 70 €/ton;
- *pellets*: cylinders of pressed sawdust having a diameter of 6 or 8 mm, height of 35 mm, moisture content of 10% in weight, average market price 180 €/ton.

Both the products have mandatory characteristics prescribed by specific standards [1]. More precisely, the pellet must fulfill the following main requirements:

- Lower Heating Value: >18 MJ/kg.
- Shape and size: cylinder with dimensions of $\phi 6 \times 35$ mm.
- Sufficient mechanical resistance in order to avoid the breaking during transportation and feeding of the burning system.
- Good capability to keep a constant energetic content.

Table 4.1 shows an example of local exploitation of biomass resources, referred to a delimited area located in the Tosco-Emiliano Apennine. In this region the amount of biomass obtained by the sustainable exploitation of forests may constitute an energy source capable to satisfy the needs of about 6600 housing units making them almost independent from the oil derivatives. Altogether, the resources available for the manufacturing of bio-fuels are essentially sawdust and waste obtained by the maintenance operations of the forests and the urban green. The sawdust comes from wood industry and is characterized by a low content of the moisture. The waste is supplied in form of pieces of tree, which usually own high moisture content.

A preliminary analysis of the business process showed that the wood waste is mainly used to manufacture chips, while pellets are basically obtained through the transformation of sawdust. As shown in Table 4.1, the yearly availability of the wood coming from sawmills is smaller than the amount coming from forest and urban management. Actually the business concerning the production of woody fuels is able to satisfy the market request of wood chips, while a big deal of the demand of pellets remains unmet.

From a technological point of view, the pellet manufacturing process employs knowledge coming from industrial fields which show severe differences with reference to the wood manufacturing sector. As detailed further on, the process is constituted by three main activities, consisting in the grinding, dewatering and pressing of the wood.

The grinding is actually performed through hammer mills which are meant to crush brittle dry materials in fine particles. Unfortunately, when such systems are used to crush the wet wood, they frequently clog up due to the formation of a mush that interrupts the flow of the material inside the machine.

The dewatering phase is performed by a thermal dehumidification employing "traditional" ovens which burn oil, methane or a part of the raw material. Due to the high moisture content that has to be removed from the wood, this phase involves a high energy consumption. Moreover, the temperature that the biomass

Table 4.1 Woody biomass resources available in the Tosco-Emiliano Apennine (tons/year)

Origin	Moisture content (in weight) (%)	Estimated availability	Estimated availability after 10 years
Wood coming from industry processes	10	5000	6000
Wood coming from forest management	35–50	25000	50000
Wood coming from urban green management	45–50	2000	10000

reaches inside the oven is a critical process parameter. If the temperature exceeds a certain limit, the dewatering phase can result in the reduction of the energetic content of the wood, because of the detaching of volatile substances such as alcohols. On the contrary, if the temperature inside the oven is too low, the dehumidification process is not able to reduce the moisture content of the wood at the required extent.

Eventually, the pressing of the sawdust is performed by machines developed within the animal feed industry, whose input raw material shows properties that consistently differ from the characteristics of the wood (mushiness, mechanical features).

As a result, these imported technologies have demonstrated low performances and efficiency.

The exposed considerations highlight that the satisfaction of the pellet market demand merely depends on the capability of the process to handle the wood waste. With reference to such issue, relevant under capacities emerge, which hinder the exploitation of the green wood as primary source of raw material for the pellet production. Since the business limitations remarkably depend on the capability of the process to provide the desired output rather than on the lack of competitiveness, the considered industrial problem can be referred to those falling into the class 1.

4.3 Application of IPPR

The application of IPPR methodology has been performed according to the roadmap developed to address the problems belonging to the class 1. For the sake of clarity the followed procedure has been reported in the Table 4.2.

In the following Sections the application of IPPR is described, clarifying the usage of the tools presented in the previous Chapter.

4.3.1 Process to Problem

As foreseen by the methodological flow, the first activity of IPPR involves the modeling of the industrial process, schematizing the constituent phases and the

Table 4.2 IPPR methodology tailored on the pellet manufacturing reengineering problem

Phase	IPPR activity	Tools
Step 1		
Process to problem	Process modelling	• Multi-domain modeling technique
	Product information elicitation	• Correlation coefficients
	Product modeling	• Relevance scale
Step 2		
Problem to ideal solution	Identification of what should be changed in the process	• Phase Overall Satisfaction metric • Resources consumption metric • Value indexes • PRAC Diagram
Step 3		
Ideal solution to physical solution	Finding physical solutions for new process implementation	• Guidelines to select process redesign tools

provided outputs. The Multi-domain modeling techniques is conveniently adopted to carry out the functional representation of the industrial process, which summarizes all the relevant information pertaining the displayed phases. Moreover, the analysis of the transformations operated by each phase is a fundamental issue for the subsequent tasks, since it highlights how the activities participate to the generation of value in terms of customer requirements. The impact of the analyzed industrial activities on the determination of the product attributes is quantified through the Correlation coefficients. Eventually, the model of the product reveals by means of the Relevance scale the importance of each customer requirement in the value building.

4.3.1.1 Process Modeling

The accomplishment of the process schematization task through the multi-domain model requires the identification of the phases and of the involved resources. The segmentation of the process into the constituent activities can be easily performed by mapping the transformations of the relevant properties characterizing the raw material and its intermediate states.

As recalled in the previous Chapter, the *Element Name Value* model provides an aid in fulfilling the task. The raw material processed during the manufacturing of pellets is constituted by wood whose properties are modified as described in the following sequence:

(1) the wood pieces undergo a reduction of the average size from 100 to 30 mm and, at the same time, a mild decrease of the moisture content from 50 to 45% in weight;

(2) the impurities inside the raw material are removed until the output reaches a degree of purity equal to the 99%;
(3) the resulting material is subjected to a further drastic reduction of the water content from 45 to 15%;
(4) the wood size is reduced to that of the sawdust (2−5 mm) and the residual moisture is adjusted to the level required for the final product (10%);
(5) the resulting sawdust is transformed in small cylinders constituting pellets, which have a diameter of about 6 mm and a length of 35 mm;
(6) eventually, the temperature is reduced from 80 to 20°C so that the pellets can be packaged in bags containing approximately 15 kg of bio-fuel.

Therefore, the analysis of the transformations clearly highlights six main phases into which the pellet manufacturing process can be segmented:

- the first trituration
- the subsequent purification
- the drastic moisture reduction through dewatering
- the second trituration
- the pressing of the sawdust namely pelletizing
- finally, the cooling and packaging of the pellet

The identified phases and the properties of the raw material that are modified, can be summarized as shown in Table 4.3, in coherence with the recalled concept of the Element Name Value.

Once the phases that form the process have been formalized, it is possible to identify the other resources involved. Since the under capacities affecting the process do not depend on the productivity, nor the time to market is a key issue, the duration of the phases in completing the assigned activity does not constitute a relevant parameter for the scope of the process analysis, thus it has been neglected. Moreover, the undesired flows have not been represented due to the absence of severe process inconveniences. Consequently, the following flows have been collected for each phase:

- Energy
- Occupied space
- Materials
- Involved human resources
- Involved technologies and know how
- Information
- Control parameters of the phases.

Table 4.4 summarizes the power consumption, the employed human resources, the required space for the equipment and machinery and other employed materials that cannot be ascribed to any of the previous categories. The quantities have been indicated according to the processing of wood giving rise to the production of 1000 kg of pellet. It is worth to notice that the dewatering phase requires a high energy consumption in order to reduce the moisture content of wood chips from 45

Table 4.3 Phase, processed flow, modified parameters of the flow, input and output values

Phase	Element	Name	Input value	Output value
A1—Trituration	Wood	Size	100 mm	30 mm
		Moisture content	50%	45%
A2—Purification	Wood	Purity	80%	99%
A3—Dewatering	Wood	Moisture content	45%	15%
A4—Second trituration	Wood	Size	30 mm	2–5 mm
		Moisture content	15%	10%
A5—Pelletizing	Sawdust	Size	2–5 mm	–
	Pellet	Shape	Undetermined	Cylinder ϕ 6 × 35 mm
A6—Cooling and packaging	Pellet	Delivering status	Untied pellets	Pellets: bags of 15 kg
		Temperature	80°C	20°

to 15% in weight. Furthermore, the pelletizing is accounted to a considerable human involvement in terms of labor, experience and know how, while the machines to perform the dewatering show the largest size. Finally, the packaging requires the purchasing of bags.

The involved technologies and the parameters governing the display of the process segments, are summarized in Table 4.5. The chipper is a cutting machine allowing the shredding of big pieces of wood into fragments. It is constituted by a rotating disc which carries cutting knifes. The purification of the wood is performed through a separator which extracts the ferrous impurities and sieves stones, soil and other residual that can compromise the quality of the bio-fuel. The dewatering phase is implemented by the usage of an oil or methane kiln, whose temperature is kept between 150 and 300°C. The reduction of wood chips into sawdust is performed by means of a mill constituted by several rotating hammers that fulfill the grinding of the chips into fine particles. A sieve guarantees that the processed material is conveyed to the following machinery only when the sawdust has reached the required size. Subsequently, the pelletizing machine presses the sawdust through calibrated holes obtained on a die and cuts the extruded material at the right length, so to get the pellets, whose surface gets quite waterproof ad a result of the operation. Eventually, after the cooling of the material carried out to avoid the melting of the bags, the packaging is performed through a machine which weighs out a quantity of pellets equivalent to 15 kg.

The collection of the above data has allowed the construction of the process model employed to manufacture the pellets according to the formalism explained in the previous Chapter. Figure 4.1 depicts the model of the A1 and A2 phases, Fig. 4.2 shows the phases A3 and A4 while Fig. 4.3 presents the model of the phases A5 and A6. It is worth to notice that the multi-domain model is capable to provide an exhaustive overview of the industrial process, allowing to focus on the relevant information within the scope of IPPR.

Table 4.4 Summary of the resources which the process uses for the manufacturing of the pellet (beyond the wood)

Phase	Energy (kW/ton)	Labour (# employees)	Space (m^2)	Materials
A1	15	2	6	–
A2	10	2	12	–
A3	350	6	21	Natural air
A4	15	2	6	–
A5	55	10	6	Natural air
A6	7.5	2	9	Bags

Table 4.5 Technologies adopted for the implementation of the process phases and relevant control parameters governing their working

Phase	Machinery	Control parameter
A1	Chipper	Cutting speed
A2	Sieving and magnetic separator	Size of the sieve
		Magnitude of the magnetic field
A3	Oven	Inlet temperature
A4	Hammer mill	Cutting speed
		Size of the sieve
A5	Pelletizing machine	Size of the calibrated holes
		Cutting length
A6	Packaging machine	Cooling time
		Packaging speed

4.3.1.2 Product Information Elicitation

Within the list of the product features intended to create value, a relevant set of attributes emerges by taking into consideration the requirements prescribed by regulations and standards. As mentioned in Sect. 4.2, the mandatory characteristics imposed in this industrial sector regard:

- a suitable energy content, in terms of *Lower Heating Value*, *LHV* (CR1)
- *Shape and dimensions* (CR2)
- *Mechanical resistanc*e (CR3)
- *Capability to preserve the heating characteristics* (CR4).

The identification of a more comprehensive record of factors that contribute to generate satisfaction is carried out by exploiting the model of the process and thinking over, in the buyer perspective, the motivations underlying the occurred transformations.

As an example on how to follow this survey approach, let's consider the *Cooling and Packaging* phase. According to the parameters summarized in Table 4.2, the phase changes the "*delivering status*" of pellets from "*untied*" to "*in bags of about 15 kg*". The objective is to discover the motivations behind the changing of this property from the viewpoint of the exigencies to be fulfilled or

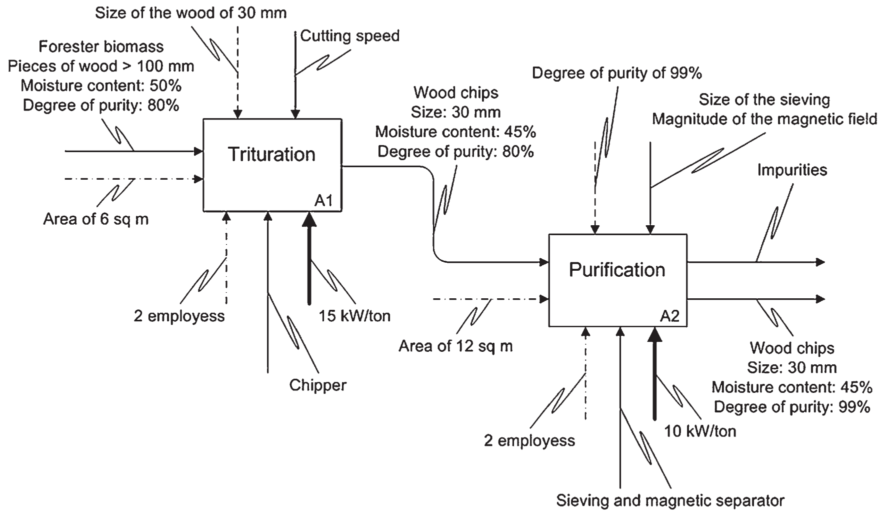

Fig. 4.1 Multi-domain model of the phases A1 and A2

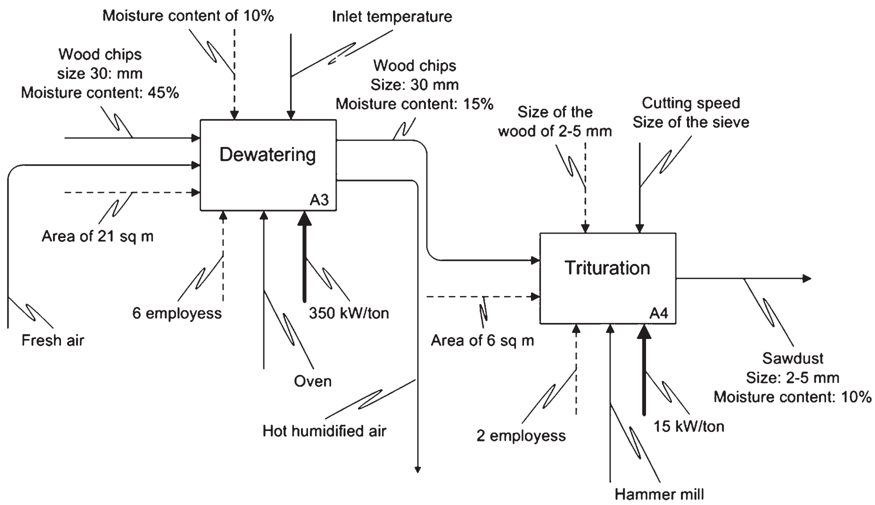

Fig. 4.2 Multi-domain model of the phases A3 and A4

benefits obtained by the customer. The formulation of questions, like the one that follows which concerns the specific modified parameter, is an useful reasoning tool for elucidating the value aspects the process is conceived for:

Within the perspective of value delivery which reason or scope motivates the transformation of the "delivering status" of pellets "untied" into "in bags of about 15 kg" along the analyzed phase?

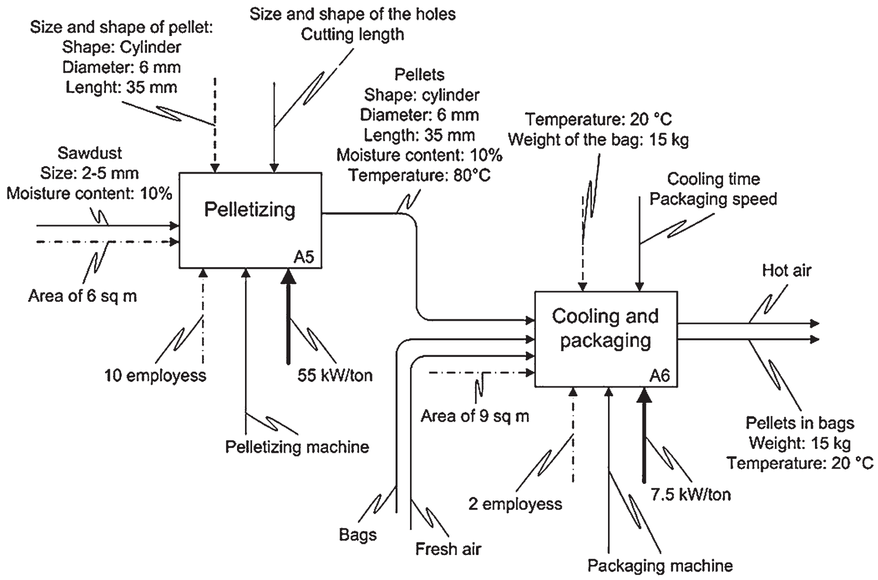

Fig. 4.3 Multi-domain model of the phases A5 and A6

The answer to this question brings to the identification of the benefits for the end-user which justify the existence of the Cooling and packaging phase. In this case the supplying of the pellets in bags of 15 kg allows an easy storage within the domestic stoves or inside the other burning systems currently available. The interest for such characteristic is confirmed also by the marketplace where the pellets are prevalently sold in bags rather than loose. Hence, the considerations performed so far suggest the "availability of the pellet in bags" as further requirement to be introduced in the attributes sample.

Beyond the just recalled requirement, the analysis of the modified parameters summarized in Table 4.3 has not highlighted additional features than those dictated by the regulations. Thus, it can be concluded that the customer requirements to be satisfied are those reported in Table 4.6.

Once the relevant product features have been individuated, it is possible to map the contribution of each phase in determining each customer requirement. In order to accomplish this task, the assessment of the relationships among the parameters modified along the process and the product features facilitates the determination of the estimated Correlation coefficients. A couple of examples is provided, concerning CR1 and CR4, about the way of computing the contribution of the phases in the fulfillment of the requirements throughout the consideration of the engineering characteristics that are accomplished. Table 4.7 monitors which technical features impact the attainment of each customer requirement. Subsequently, the involvement of each phase in obtaining each customer requirement is summarized in Table 4.8.

Table 4.6 Customer requirements to be satisfied for the pellet

Attribute
CR1—Lower heating value—LHV
CR2—Shape and dimensions
CR3—Mechanical resistance
CR4—Capability to preserve the heating characteristics
CR5—Availability in bags

Table 4.7 Relationships among modified properties of the main flow of raw material and the customer requirements

Modified parameters	CR1	CR2	CR3	CR4	CR5
Size		X			
Moisture content	X				
Purity			X	X	
Shape		X	X	X	X
Delivering status					X

Table 4.7 plainly shows that the unique technical parameter impacting the energy content of the pellet is represented by the moisture included in the wood. It can be thus stated that the phases contributing in the attainment of CR1 are those which modify the moisture content of the processed wood, hence A1—Trituration, A3—Dewatering and A4—Second trituration. The desired level of water removal is obtained by the partial contributions depicted in Table 4.3, hence:

- Moisture reduction operated by the phase A1 (Δ_{A1}): 5%
- Moisture reduction operated by the phase A3 (Δ_{A3}): 30%
- Moisture reduction operated by the phase A4 (Δ_{A4}): 5%

Therefore, the values of the correlation coefficients pertaining the CR1 and the phases A1, A3 and A4 are calculated as in the followings:

$$k_{11} = \Delta_{A1}/(\Delta_{A1} + \Delta_{A3} + \Delta_{A4}) = 5/40 = 0.12 \approx 0.1$$
$$k_{13} = \Delta_{A3}/(\Delta_{A1} + \Delta_{A3} + \Delta_{A4}) = 30/40 = 0.75 \approx 0.8$$
$$k_{14} = \Delta_{A4}/(\Delta_{A1} + \Delta_{A3} + \Delta_{A4}) = 5/40 = 0.12 \approx 0.1$$

Furthermore, if we consider the CR4—Capability to preserve the heating characteristics, such a feature is guaranteed through a high degree of the wood purity and by waterproof characteristics of the pellet surface. As suggested in Chap. 3 for the cases ascribable to this situation, the adopted criterion for the calculation of the correlation coefficients is based on a weighted sum of the partial contributions offered by each property in determining the analyzed CR. Specifically, the capability to preserve the heating characteristics are influenced much more consistently by the waterproofing of the pellet surface rather than on the wood purity. Consequently the former engineering characteristic holds a greater relevance (80% as estimated by sector experts) than the latter in the attainment of the treated customer requirement. The required purity of the wood is achieved

Table 4.8 Role played by each phase in generating each customer requirement

Phase	CR1	CR2	CR3	CR4	CR5
A1—Trituration	X	X			
A2—Purification			X	X	
A3—Dewatering	X				
A4—Second trituration	X	X			
A5—Pelletizing		X	X	X	X
A6—Cooling and packaging					X

through the Purification (A2); conversely the requested waterproof qualities are attained through the Pelletizing (A5). It can be concluded that the CR4 is determined as a result of the concomitance of the two cited phases. According to the performed considerations, the extent of the contributions of the Purification and of the Pelletizing, can be calculated as follows:

- Improvement of the degree of purity performed by A2 (Δ_{A2}): 100%
- Improvement of the degree of purity performed by A5 (Δ_{A5}): 0%
- Attainment of the desired level of waterproof operated through A2 (Δ_{A2}): 0%
- Attainment of the desired level of waterproof operated through A5 (Δ_{A5}): 100%
- Importance of the degree of purity in determining the CR4 (W_1): 0.2
- Importance of the waterproof properties in generating the CR4 (W_2): 0.8

$$k_{42} = \Delta_{A2}/(\Delta_{A2} + \Delta_{A5}) \times W_1 = 0.2$$
$$k_{45} = \Delta_{A2}/(\Delta_{A2} + \Delta_{A2}) \times W_2 = 0.8$$

The calculation of the further correlation coefficients according to the suggested criteria have led to the values summarized in Table 4.9.

4.3.1.3 Product Modeling

The present activity concerns the determination of the importance that each customer requirement owns in impacting the value perceived by the end-user. According to the indications suggested in Chap. 3, this task is carried out by assigning a score to each product feature, that is expressed through a natural number included in the interval 1–5 of a Likert scale.

Since the heating capability is the characteristic of the pellet which is mostly appreciated by the customer during the use of such bio-fuel, representing the main provided benefit, its degree of importance can be evaluated with the maximum score. The size, the mechanical resistance and the capability to preserve the heating power can be accounted as requirements aimed at prevalently meeting the functional exigencies of the burning systems. Although these features strongly contribute to the prevention of safety problems, their offering does not impact the perception of the customer at the maximum extent. Therefore, notwithstanding the

Table 4.9 Correlation coefficients quantifying the relationships phase versus customer requirements

Phase	CR1	CR2	CR3	CR4	CR5
A1	0,1	0,2	0	0	0
A2	0	0	0,1	0,2	0
A3	0,8	0	0	0	0
A4	0,1	0,1	0	0	0
A5	0	0,7	0,9	0,8	0,1
A6	0	0	0	0	0,9

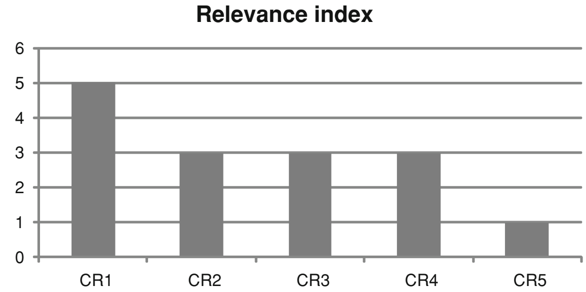

Fig. 4.4 Relevance coefficients expressing the importance of each customer requirement in determining the customer perceived value

importance of the role played by these characteristics, they are assigned a relevance index inferior than that of the Lower Heating Value. Finally, the delivery of pellets in bags is a feature which facilitates the usage of the product, by easing its storage, transportation and handling. It can be considered as an additional feature whose presence is appreciated by the customer, but, however, its relevance in determining the perceived value is considerably more limited with respect to the other characteristics.

According to the above performed considerations, the assigned relevance indexes are summarized in Fig. 4.4.

4.3.2 Problem to Ideal Solution

The tools suggested by PVA are hereinafter applied in order to identify the main process under capacities which hinder the attainment of the desired output of the process, according to the resources available for the pellet manufacturing.

4.3.2.1 Phase Overall Satisfaction

The calculation of the *Phase Overall Satisfaction* (POS), representing the extent that each activity has in determining the customer contentment, is determined through the following formula:

$$POS_j = \sum_i k_{ij} \times R_i.$$

Table 4.10 POS of the j-th phase

Phase	POS_j	$POS_j(\%)$
A1—Trituration	1,2	8,2
A2—Purification	0,9	6,0
A3—Dewatering	3,8	25,0
A4—Trituration	0,9	6,2
A5—Pelletizing	7,3	48,7
A6—Cooling and packaging	0,9	5,3

Table 4.10 summarizes the obtained POS_j of each process phase (expressed in a non-dimensional form and as a percentage).

The POS coefficient highlight the central role of A1, A3 and A5 in determining the customer contentment. Besides, as demonstrated by the k_{ij} coefficients and the relevance indexes R_i, they are fundamental in the attainment of the most relevant product features.

4.3.2.2 Resources Consumption

The calculation of the *Resources consumption* (RES) index, has to be performed through the usage of the expression introduced in Chap. 2:

$$RES_j = c \times C_j + t \times T_j + h \times HF_j.$$

However, as recalled in the previous section, the time to market does not represent a critical factor for the analyzed business process; moreover, the manufacturing of pellets from wood waste does not show remarkably lower speed than the traditional production based on sawdust. Hence, the duration of the production phases is not considered relevant for the examined value creation process, as well as the undesired effects emerging by the sequence of the process segments (e.g. noise, vibrations, difficulties related to the maintenance, etc.), that are not actually displayed. Therefore, the global resources estimation has neglected operating times and drawbacks, focusing the attention just on the monetary expenditures. In other terms, the coefficients, t and h are null in the specific case study.

The extent of the channeled resources has been assessed by assuming a reference production of 1 ton of pellet. More specifically, the analysis has included the expenditures related to the labor, the space occupied by the equipment, the consumed energy and materials, subsequently evaluated through a monetary metric.

The inventory costs related to the acquisition of the necessary quantity of wood have been neglected since such kind of biomass is still considered alike waste and currently it does not possess any economic value. The energy costs have been calculated with reference to the consumption of each phase and the current price of the electric/thermal power. The operating expenses related to the labor have been calculated through the accounted involvement of the personnel and the hourly cost of the employed workers. The inventory costs involved for the space occupied by the plants have been calculated dividing the monthly amount of real estate expenditures for the industrial site by the potential production of the plant in the same period. Then, such expenditures have been split to calculate the amount accounted to each process step taking into consideration the ratio of the space occupied by the machinery utilized to perform the phases. Finally, the inventory costs of the consumed materials have been assessed dividing the annual expenditures to purchase these resources by the number of pellet batches potentially produced in a year.

Thus, the expenditure values have been calculated through the following rules:

- *Energy expenditures = phase required energy × power cost;*
- *Labor expenditures = phase employed labor hours in a year × hourly labor cost index/number of pellet batches produced in a year.*
- *Space expenditures = (ratio of space occupation for the phase machinery) × (monthly real estate expenditure)/(number of pellet batches potentially produced in a month).*
- *Material expenditures = costs to purchase the needed materials for a ton of manufactured pellet.*

Some examples are herein proposed in order to clarify the assessment procedure of these expenditures. The considered values for the resources consumption are those summarized in Table 4.4.

With reference to the A1 phase, the cost to purchase 1 kW of electric power is about 0.2 €/kW, hence the expenditures for the trituration of 1 ton of wood are:

$$\textit{Energy expenditures}\,(A1) = 0.2 \times 1.5 \approx 3\,€/\text{ton}$$

On the other hand, if the cost of 1 kW of thermal power needed by the oven is 0.11 €, the energy expenditures for the Dewatering phase (A3) is evaluated in:

$$\textit{Energy expenditures}\,(A3) = 0.11 \times 350 \approx 38\,€/\text{ton}$$

Moreover, if the hourly labor cost index is 17.5 €/h, each worker dedicates his/her full time to this operation (1516 h expected in a year), the yearly production can be estimated in 27000 tons, such kind of expenditures required by the Pelletizing phase can be evaluated in:

$$\textit{Energy expenditures}\,(A2) = 2 \times 1516 \times 17.5/27000 \approx 2\,€/\text{ton}$$

Let's now take into account the expenditures involved in the Purification to "acquire" the needed space where the phase is performed. The number of pellet batches produced in a month can be easily obtained dividing the yearly availability of wood resources by the number of labor months included in a year:

$$\textit{Number of pellet batches potentially produced in a month} = 27000/11 = 2454\,\text{ton/month}$$

Furthermore, the ratio of space occupation (as emerging from Table 4.3 by considering the room needed for the phase and that required for the whole process) for the employed purification machinery is:

$$\textit{Ratio of space occupation for the phase machinery}\,(A2) = 12/60 = 0.2$$

If the monthly real estate cost is quantified in 25 k€, the space expenditures for the Purification phase can be evaluated in:

$$\textit{Space expenditures}\,(A2) = 0.2 \times 25000/(2454) \approx 2\,€/\text{ton}$$

Eventually, considering the Packaging phase, if the price of a bag is 0.10 € and remembering that each bag can contain 15 kg of wood pellets, the expenditures of material are:

$$\textit{Material expenditures}\ \ (A6) = 0.10 \times 1000/15 = 6,7\,€/\text{ton}$$

By following the explained criteria, the RES index of each phase has been evaluated. The obtained values are reported in the Table 4.11 (in €/ton and in percentage in the last column).

The evaluation of the resources consumption shows that, among the six phases of the process, the Dewatering of the wood and the Pelletizing are the most expensive with a massive impact of the former on the whole efficiency of the process. Furthermore, the overall cost to manufacture 1 ton of pellet exceeds half the price in the marketplace, giving rise to low margin of revenues for the business process.

4.3.2.3 Overall Value and PRAC Diagram

The *Overall Value* index of the process phases has been calculated as the ratio between the POS and the RES coefficients, both expressed as percentages. The resulting values are shown in the Table 4.12. Moreover, the *POS versus RES Assessment Chart* (PRAC), shown in Fig. 4.5, has been built with the aim of providing a clear representation of the business process analysis.

The conjoint analysis of the OV index and the PRAC leads to several directions of investigation devoted to the improvement of the manufacturing process.

As shown in Table 4.12, the dewatering (A3) owns the smallest OV index, thus it represents the major bottleneck of the business process. Such outcome emerges as a result of the substantial amount of resources dedicated to the working of the phase. Furthermore, the rank of the OV indexes shows that the second critical phase is the trituration (A4), which provides a poor contribution in determining the customer satisfaction and presents a limited consumption of resources. According to Fig. 4.5, the purification (A2), the packaging (A6) and first the trituration (A1) show remarkable analogies with the discussed (A4). Eventually, the pelletization (A5) is deemed as a phase which considerably contributes to the customer satisfaction.

Table 4.11 Resources consumption index of each phase

Phase	Energy	Labour	Space	Material	RES_j	$RES_j(\%)$
A1—Trituration	3	2	1	–	6	6.1
A2—Purification	2	2	2	–	6	6.1
A3—Dewatering	38	5.9	3.5	–	47.4	47.9
A4—Second trituration	3	2	1	–	6	6.1
A5—Pelletizing	11	9.8	1	–	21.8	22
A6—Cooling and packaging	1.5	2	1.5	6.7	11.7	11.8

Energy, labour and space resources are expressed in €/ton

Table 4.12 Overall Value index of each phase

Phase	OV_j	$OV_j(\%)$
A1—Trituration	0.38	34.3
A2—Purification	0.15	13.4
A3—Dewatering	0.06	5.7
A4—Trituration	0.12	10.4
A5—Pelletizing	0.33	30
A6—Cooling and packaging	0.07	6.1

The whole analysis suggests that primary fundamental action to be pursued consists in the improvement of the dewatering phases by developing more efficient technologies for wood pellet production. Moreover, given the characteristics of the (A4), strategies should be evaluated in order to migrate its function to other phases or integrate the delivery of additional benefits. Such indications pertain also the (A1), (A2) and (A6), although the reengineering efforts for such phases are not of overriding importance. Eventually, although the pelletization holds a high OV coefficient, the performed analysis reveals a not negligible resources consumption for this phase (Table 4.11), thus technologies enhancement aimed at further increasing its efficiency would be welcome in each case.

4.3.3 Ideal Solution to Physical Solution

The value-oriented process analysis has further shed light on the consistent limitations concerning the production of pellet starting from wood waste, due to the experimental technologies. The tools and machinery employed so far, with a particular emphasis on the dewatering process, result scarcely efficient to treat biomass with a high moisture content. In order to obtain pellet with a satisfying energetic yield, the moisture content initially present in the green biomass (approximately 50% in weight) must be drastically reduced. The technologies based on thermal dewatering use rotating or fluid bed furnaces that are fed by methane, oils, or a part of the raw biomass. This involves high fuel consumption, due to the meaningful

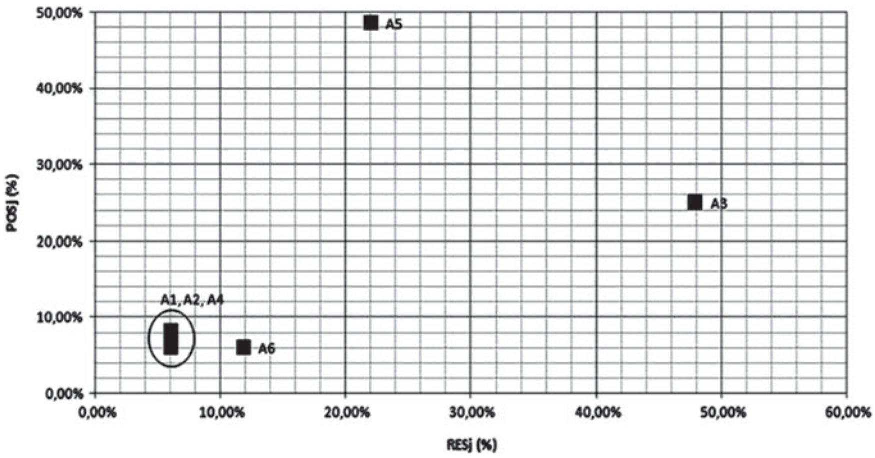

Fig. 4.5 PRAC of the pellet manufacturing process

amount of water that should be extracted. As experiences illustrate, a critical factor for the efficiency of the dehydration is the size of the treated material. Indeed, the dewatering phase could be strongly enhanced if the size of the biomass at the inlet of the kiln could be reduced, but, unfortunately the current systems for wood grinding are not able to treat wet biomass. On the other hand, the technologies currently positioned downstream of the dewatering that impact the structure of the biomass (i.e. the trituration and the pelletizing) do not show any opportunity to support the drying, so the bottleneck of the process can hardly be substituted.

According to outcomes of the analysis and the preceding considerations, the most beneficial directions to be followed in order to make the process convenient would regard the adoption of technologies capable to:

- dewater the chips, reducing considerably their moisture from 50% to very low values, by employing a smaller amount of energy than that required by the present systems;
- triturate the wood chips into finer particles during other process segments, favorably along a reengineered dewatering phase.

These exigencies constitutes well defined functional requirements that the new process must satisfy.

The definition of the projected process improvements has led to the formulation of two well specified technical problems, whereas the first holds primary importance:

(1) How is possible to reduce the resources consumption of the dewatering phase?
(2) Is it possible to integrate elsewhere the functions performed within the trituration? Can the redesign of the dewatering operations include the milling functions?

Generally speaking, such a design task is related to the identification of technical solutions capable to efficiently fulfill the expected phase performances, i.e. the trituration of the wood chips up to the sizes required for the pelletization as well as a suitable extraction of the moisture from the wood.

With regards to the tools selection criteria exposed in the Chap. 3, the prior redesign problem falls into the category of identifying technical solutions aimed at minimizing the process expenditures. Thus, the principles of *Class 2* with regards to the *76 Standard Solutions* of TRIZ, result as candidate techniques to support this task.

According to the exploitation of the mentioned tools, the research of working principles has been focused on the identification of alternative physical solutions for the dewatering phase. Specifically, high speed mechanical energy has resulted in a powerful resource to separate water from wood particles during the milling process. The individuation of such solution has brought about particular interest due to the possibility to integrate (at least partially) the trituration and the dewatering. Moreover, if ultrasonic waves are generated by means of high speed shocks, they can further contribute to the moisture reduction.

A specific patent search to validate such a conceptual solution has produced the individuation of three patents [2–4] adopting the same physical principle to pulverize and dry several kinds of raw materials. At least one of these patents has been converted into a real product [5]: a rotor equipped with chains or knifes operates the trituration of the material, by shooting the particles towards the walls of the machine. The impact transforms the kinetic energy of the particle into vibration energy, thus the particles and the water vibrates: this allows the separation of the different materials. According to the datasheet supplied by the producer, such a system is able to reduce the moisture content of the wood from 60 to 10% and the particle size up to 1 mm. The most relevant property of this technology is a very limited energy consumption, about three times less than a traditional heat based dehumidification.

Unfortunately such a technology is not suitable to be used during forestry operations since it has dimensions and weight that do not allow transportation and management in the forest areas. With the aim of overcoming this limitation, a new mechanical system which implements the same physical principle adopted in [5] through a different architecture so to avoid patent infringement, has been designed and developed by the authors and other colleagues [6]. Such a system has a size that allows its transportation and installation in the woody areas where forestry operations take place. This technology is less expensive than the traditional one in terms of both investments and maintenance costs. Tests also revealed that the biomass can reach the required moisture content for pellet production after very few milling/dewatering cycles.

4.4 Discussion of the Outcomes

The present Section discusses the reliability of the outcomes of the process analysis performed within IPPR, regardless the effectiveness of the extrapolated physical solution, for which further verifications are still required.

The analysis of the scientific and technical literature in the field of renewable energy confirms that the drying of the woody biomass is a critical phase in the production process of pellet starting from green wood.

In [7, 8] it is clearly explained that the drying process based on thermal heating has a not negligible impact on both quality and production costs of wood pellet and new drying systems should be developed in order to make the pellet manufacturing process more efficient in terms of energy consumption and product characteristics delivered to the end-user.

In [9] it is claimed that in wood manufacturing industry, drying is considered the most relevant matter determining problems in process controllability and high energy expenditures. Several studies have been carried out and several technologies have been introduced to improve this phase in wood industry, as summarized in [10], showing however the absence of a dominant design or standard.

Therefore, the aforementioned researches widely confirm the results obtained through the application of the proposed methodology.

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Chapter 5
Application of IPPR to the Reengineering Problems of Class 2

5.1 Introduction: The Italian Accessible Fashion Footwear Industry

The methodology has been applied to a branch of the Italian footwear industry that has strongly contributed to the national industrial growth in the second half of the twentieth century. The sector played a significant role in the success of products marked “Made in Italy”, synonym of prestige and glamour, but is actually facing a crisis period, although the style of the manufactured shoes is still considered original and fashionable. Particular difficulties are encountered by shoe factories and industrial districts producing stylish and high-quality items, but not possessing the assets for recruiting top fashion gurus.

More in detail, the Italian footwear sector comprises a group of famous brands and a multitude of so called “accessible fashion” factories. The brands belong mostly to luxury market segment and determine or somehow considerably impact the emerging fashion trends. The high fashion industries show a good market share, since their success is based on customers’ identification with the brand. The products of the accessible fashion enterprises address the consumers of a large income bracket. These firms cannot base their competition on a strategy swiveling on low selling prices, due to the higher margins displayed by industries of the emerging countries, whereas the labor is much cheaper. Among the others, the worldwide market of discount shoes is dominated by Asian products and the economical trends highlight further reductions of Western productions in this business. On the other hand, the biggest majority of accessible fashion factories cannot aspire to enter the high-end market, because they miss the means, the organizational structure and the know-how of the brands.

In such context, IPPR was applied with the aim of analyzing the whole business process of the firms facing market difficulties, in order to remark the greatest value bottlenecks and the most promising opportunities for improving the competitiveness.

F. Rotini et al., *Re-engineering of Products and Processes*,

Springer Series in Advanced Manufacturing, DOI: 10.1007/978-1-4471-4017-7_5

The following Section describes more in detail the problems faced by the accessible fashion firms, underlining how the display of the business process contributes to the current crisis. Subsequently, Sect. 5.3 illustrates the application of IPPR leading to the comparative value analysis among the business process phases in charge of the shoe factories. Eventually, Sect. 5.4 presents a brief discussion on the obtained outcomes with the aim of highlighting their robustness and effectiveness within a reengineering initiative.

5.2 General Overview of the Business Process

The yearly activity of the footwear industry is mainly based on two market seasons (summer and winter), resulting in a strong influence on the organization of production and manufacturing activities. The performed business process may be subdivided in three main blocks of phases, briefly described in the followings.

The seasonal process begins with the realization of a big amount of prototypes. Such stage is aimed at providing a collection of samples according to style and relevant features of the shoes that are attributed by fashion designers on the basis of the vogue trends. The factories sell their products on the basis of these samples, in the shape of three-dimensional models, previously submitted to several tests. Among the outputs of the prototyping, a very important issue is the definition of the bill of materials for each shoe model included in the collection that is required for the scheduling of the manufacturing process, the purchases planning and the determination of the prices.

After the prices are set on the basis of the expected cost and potential commercial success of the shoes, the seasonal offer of the firm is fixed. This enables the starting of the selling stage, commonly carried out by agents through the intensive participation to sector fairs. In this phase the factories receive selling orders for the presented shoes, on the basis of which they plan the manufacturing activities. During this stage the agents and the sellers continuously update the factory about the sold batches, so that the scheduling is readjusted according to more and more reliable forecasts.

Subsequently, once the initial planning of the purchases and the manufacturing activities is completed, the firm keeps in coordinating the shoes production as the process progresses. The manufacturing manager and the purchases responsible are in charge of continuously supervising the accuracy and the timeliness of the operations. The shoes manufacturing is constituted by several sub-tasks, such as production of working tools (i.e., dies and shoe lasts), acquisition of leather, heels and components, uppers manufacturing and sewing, assembling etc. Due to economic convenience, most of the listed activities are carried by subcontractors (usually both offshore and onshore). The batches of shoes are then shipped to the retailers, representing the direct customers of the factories. The enterprise has to put attention on the flawed products along the whole manufacturing stage. Figure 5.1 provides a graphical representation of the main activities involved in the classical business process in charge of the shoe factories.

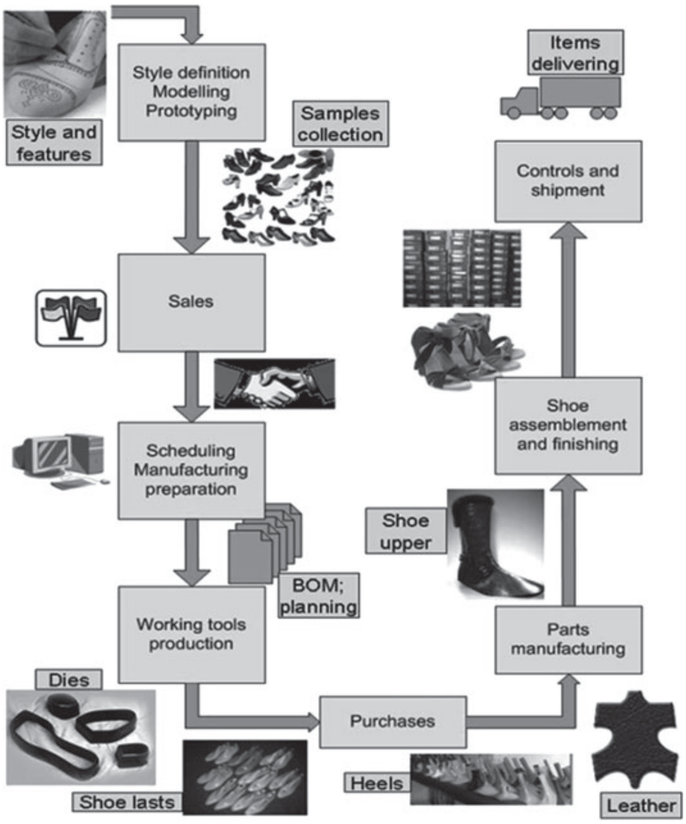

Fig. 5.1 Schematization of the business process relevant for the footwear industry

Due to the characteristics of the business process, the collection of the shoe samples must-be prepared substantially in advance with respect to the buying of the end-users. In the meantime, the powerful influence of the brands induces strong changes in the vogue trends, potentially resulting in a mismatch between the tastes of the final consumers and the stylistic features of the items produced by many shoe factories. This generates large amounts of unsold goods coming from the accessible fashion industry, leading to retailers' dissatisfaction towards these firms and influencing negatively the repurchase intentions. As a consequence, the accessible fashion firms lose relevant market shares.

Hence, on the basis of the previous considerations, the shoe factories belonging to the accessible market suffer of a lack of competitiveness, since the provided output, although already sold, is not able to fulfill the style expectations of the end-users.

As a result, the present business process requires a reengineering strategy to fill the gap between the offered product features and the wishes of the final consumers that are influenced by the emblazoned labels. Given the mismatch between the industrial process and the expected outputs, resulting in a general lack of

Table 5.1 IPPR methodology customized for the reengineering problems belonging to the class 2

Phase	IPPR activity	Tools
Step 1		
Process to problem	Process modelling	• Multi-domain modeling technique
	Product information elicitation	• CRs checklist • Correlation coefficients
	Product modeling	• Relevance scale • Kano model
Step 2		
Problem to ideal solution	Identification of what should be changed in the process	• Satisfaction/dissatisfaction metrics • Phase overall satisfaction metric • Resources consumption metric • Value indexes • Value assessment chart
Step 3		
Ideal solution to physical solution	Finding physical solutions for new process implementation	• Guidelines to select process redesign tools

competitiveness, the considered situation can be advantageously analyzed by means of the tools proposed within the class 2 of reengineering problems. This allows to point out the main process criticalities with regards to the supply of customer value.

5.3 Application of IPPR

The aim of the present Section is to describe the application of IPPR in the version tailored to treat the reengineering problems falling into the class 2.

The step by step sequence of activities, recalled in Table 5.1, leads from the segmentation of the process to the individuation of the value bottlenecks and the consequent favorable directions for the business reorientation.

5.3.1 Process to Problem

The first activity of IPPR requires the modeling of both the industrial process and its outputs in terms of relevant product features. The multi-domain modeling technique has been employed to build the functional scheme of the business process. Hence, the product representation has been carried out by means of the Kano model and the relevance scale, revealing the role played by each customer requirement in determining the satisfaction for the buyer. Finally, the relationships between the phases and the delivered product features have been investigated and expressed through the correlation coefficients, in order to subsequently estimate the contribution of each process segment in the determination of the whole value.

5.3.1.1 Process Modeling

As previously recalled, the companies belonging to the accessible fashion footwear industry are characterized by production processes sharing considerable commonalities. Therefore, the specific scope of IPPR employment has resulted in the attainment of strategic directions for the evolution of the whole sector rather than for a single firm. According to this aim, the building of a reliable multi-domain model of the business process has required a deep exploration of the sector, with a particular effort dedicated to individuate values of the involved coefficients representative for the whole set of investigated firms. More specifically, the presented analysis refers to a large sample of firms composing an industrial footwear district in central Italy.

At first, the information referable to the sketch of the business process presented in Sect. 5.2, has been enriched through the consultation of technical publications in the field. Such an activity has allowed the subdivision of the process into the set of relevant phases, then confirmed throughout the subsequent information gathering tasks. The segmentation of the process and the individuation of the main flows has been performed by using the criteria and the formalisms of IDEF0 model (recalled in the Appendix A), as suggested in the IPPR roadmap. Figure 5.2 illustrates the sectioning of the industrial process into three main blocks of activities and depicts, although not in charge of the shoe factory, also the retailing phase, which produces relevant feedbacks on the future collections. The three principal blocks are further partitioned, giving rise to the schemes of Figs. 5.3, 5.4, 5.5.

According to the above representation, the business process can be segmented into the following main phases, whose label is in brackets:

- the process starts with the determination of the proper footwear style in charge of experts which analyze the trends of the big firms and fine-tune the specifications for the seasonal collection (A11);
- the collection is designed (A12);
- the samples of the shoes are produced, as well as the technical documentation is provided in order to ease the subsequent schedule of the manufacturing (A13);
- the selling price is established for each kind of shoe and the shoe factory participates to the main sector fairs, whereas the negotiations with interested retailers take place (A21);
- the selling agents carry on collecting the orders (A22);
- according to the received orders, the manufacturing operations and the purchasing of the needed components are planned (A31);

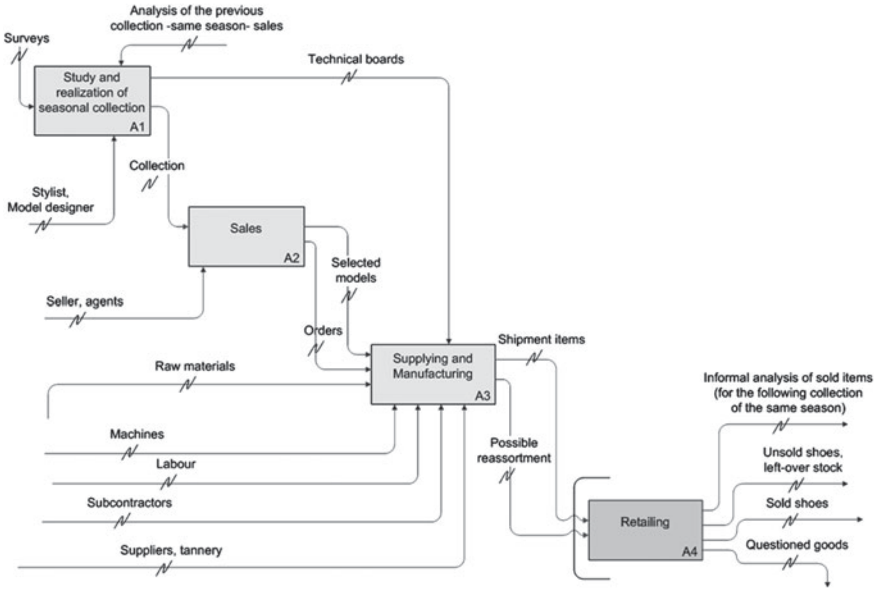

Fig. 5.2 Layout of the business process relevant for the shoe factories, operating in the accessible fashion bracket, represented through IDEF0 model

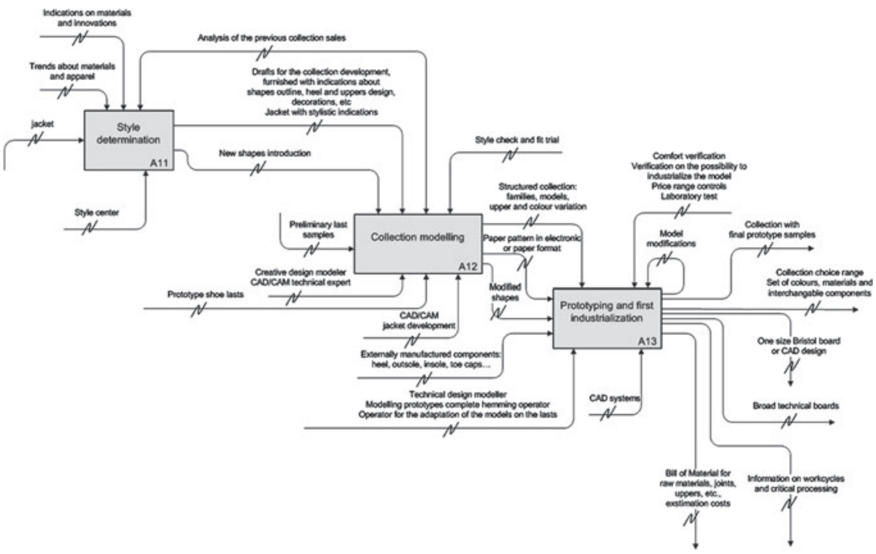

Fig. 5.3 Segmentation of the block of activities, aiming at the ideation, design and prototyping of the shoes collection through IDEF0 model

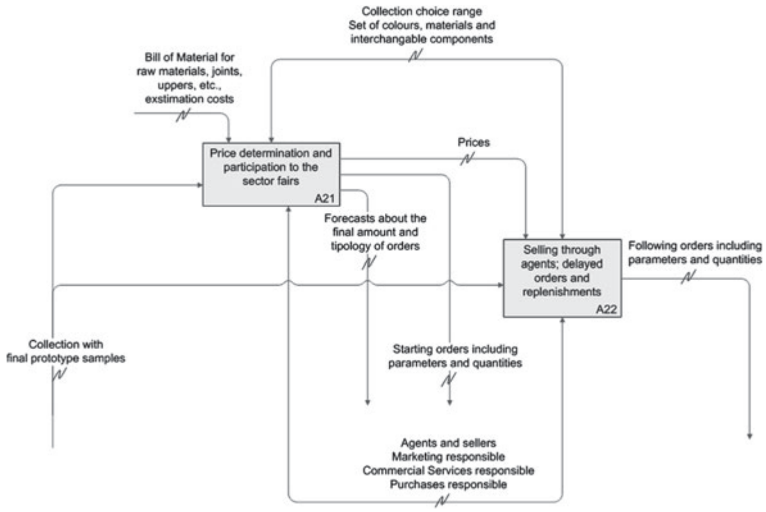

Fig. 5.4 IDEF0 scheme of the main phases addressed at the selling the designed shoes collection

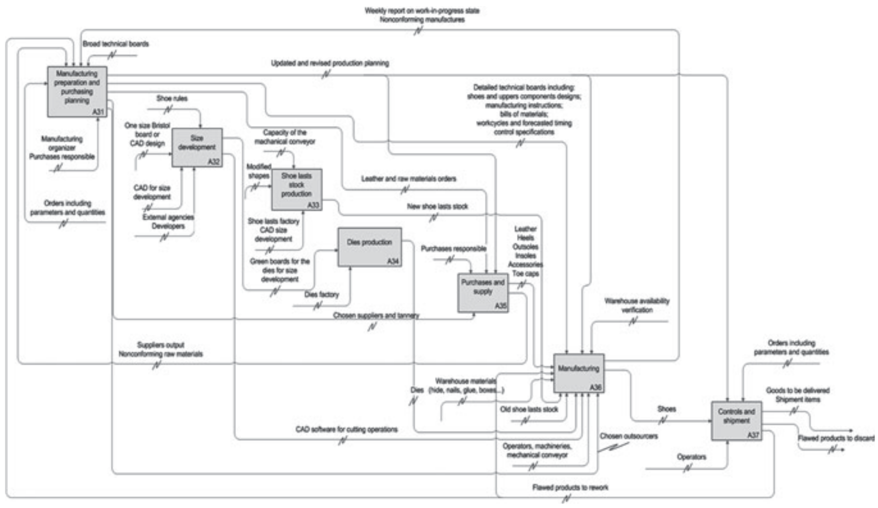

Fig. 5.5 IDEF0 model of the operations addressed at finalizing the shoes production according to the previous phases

- the different sizes are developed with regards to each sold item belonging to the collection (A32);
- the shoe lasts are manufactured by specialized parties or units (A33);
- the dies for the cutting of the different parts of the shoe are produced (A34);
- the purchasing of the needed parts is carried out (A35);

- the seasonal batch of shoes is manufactured (A36);
- the produced items are verified in order to check their compliance with the standards of quality and the shoes are shipped to the retailers (A37).

The second stage of the analysis has been supported by a group of experts, which was constituted by an analyst having 20 years of practice in the field and three entrepreneurs. The collaboration of the sample of specialists was aimed at gaining further understanding about the manufacturing activities, the involved organizational skills and the relevant industrial practices. As a result of the additional information, some key phases have been further segmented. However, according to the scope of representing a business condition relevant for a whole sector, it emerged that the individuated phases could not be further characterized by indexes on which a considerable sample of firms could converge. In other words, the characterizing coefficients of the individuated segments, within IPPR, present an extreme variability according to each single enterprise. Indeed, for instance, the employment of the resources in the sub-operations is strongly dependent on the specific company. The kind of shoes (classical shoes, sandals, boots, moccasins etc.), the characterizing stylistic features (use of accessories, presence of decorations and seams), the reference markets (South Europe, North Europe, USA, Russia, Japan etc.), the gender of the end-users, the collection (summer or winter) heavily influence the process practices, resulting in noticeably different use of resources (financial commitments, duration of the activities, employed labor, carefulness in operations performing.

For the sake of completeness, the acquisition of the components usually regards the purchase of the required amount of leather, heels, soles, shoe tips, insoles and additional accessories, e.g. zips, studs and clasps. The manufacturing of the shoes, according to the design and the orders, starts with the cut of the leather in order to obtain the required pieces that have to form the uppers, the strips to be applied to the heels and the hemlines for the soles. The suitable shapes and measures of the cut leather are obtained thanks to the prior preparation of the sizes and of the dies. The parts composing the shoe uppers are sewn by the binding unit, while the bands are joined to the heels and the soles. The purchased parts and the semi-finished components are assembled and shaped throughout the shoe lasts. At last the shoes are finished by means of the operators working at the conveyor.

The final resulting multi-domain model has been definitively built by visiting the shop floors of three shoe factories and by consulting their production managers. The refinement of the business process model has given rise to the quantification of the channeled resources, assessing the ordinary elapsed times and ratios of monetary expenditures addressed to each phase.

The last investigation stage has indeed allowed to obtain further relevant indications, such as:

- common problems faced in the business planning;
- constraints related to the manufacturing process (e.g. common production capacity of the devices, sequence of the operations to be performed, rules to be followed);

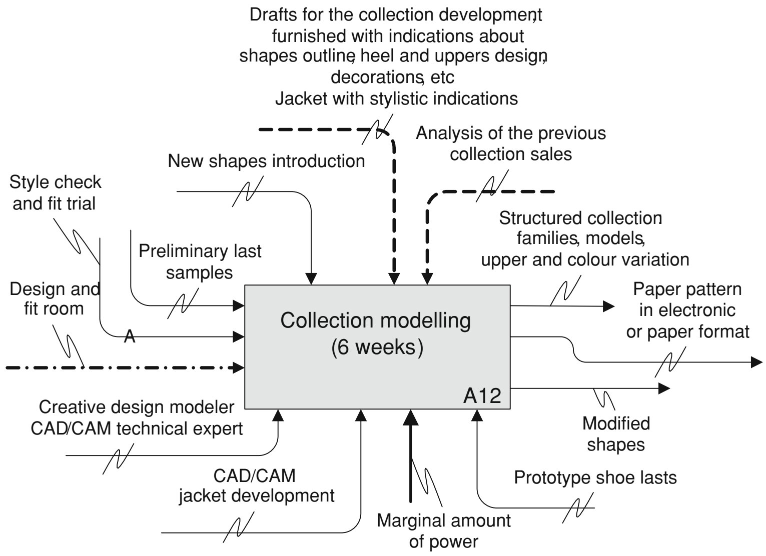

Fig. 5.6 Schematization of the phase A12 of the business process through the multi-domain model proposed within IPPR

- extent of the involved resources in terms of incurred costs;
- employed personnel;
- common duration of the phases.

According to the gathered information, the business process has been schematized by means of the proposed multi-domain model. An exemplary phase is reported, as illustrated in Fig. 5.6, while the whole schematization is omitted for space reasons.

5.3.1.2 Product Information Elicitation

The commonalities existing in the investigated sector allow to provide a shared representative scheme of the process output. The activity illustrated in the present paragraph brings to the definition of the main product features and the estimation of the phases contribution to their fulfillment, throughout the consultation of the recalled sector experts involved in the reengineering task.

The determination of the relevant customer requirements has taken into account the fact that the process operates in a B2B environment. Therefore, the relevant product attributes deal with both the direct customer (i.e. the retailer, the outlet) and the end-user of the shoes, which follows in the value chain. The record of customer requirements has been extracted by resorting to both the process model and the CRs checklist. In the followings, some examples are provided to illustrate the elicitation process of the product features playing any role in the delivery of satisfaction.

Table 5.2 Set of relevant customer requirements for the business process of the footwear industry

CR	Business process attributes
CR1	Customization possibility
CR2	Link with the apparel sector
CR3	Comfort
CR4	Technical and healthy properties
CR5	Standard sizes supply
CR6	Resistance and duration
CR7	Components completeness
CR8	Manufacturing care
CR9	Care in the order dispatching
CR10	Non-standard sizes availability
CR11	Appeal, lines, shapes
CR12	Colours and materials variety
CR13	Possibility of developing faithful customers
CR14	Offer potentiality

With reference to the customer dimension and the marketplace, the sector experts have individuated relevant competing factors, which concern, more specifically, the *carefulness in dispatching the orders* (then labeled as CR9) and the *variety* (CR12) of the shoes belonging to the seasonal collection. On the other hand, several customer requirements regard the sphere of the end-user and emerge by analyzing the business process model and focusing on the transformations occurring along the phases. For instance, the way the collection modeling is performed, including a preliminary testing of the prototype footwear, leads to the individuation of the shoes *comfort* (CR3) as a significant competing factor. Additionally the consultation of the CRs checklist has allowed the identification of further attributes, which were previously neglected, e.g. the term "the opportunity provided to advantageously employ the product for not standard users or disabled people" has given the chance to consider the value exerted by ensuring the capability to provide *non-standard sizes* (CR10) of the shoes.

The mechanism for the elicitation of the product attributes has given rise to the list of customer requirements depicted in Table 5.2, subsequently employed for the purpose of the IPPR application. It is worth to notice that the number of customer requirements (14) is similar to that of the investigated phases (12); thus, the analysis respects the indication to employ a ratio between these two quantities ranging from 1/2 to 2.

Most of the customer requirements are not referable to quantitative and measurable parameters, nor they can be considered as a result of one or more engineering characteristics. The determination of the correlation coefficients has then involved insightful considerations of the sector experts, in order to converge towards a shared scheme of the phases contributions in attaining the customer requirements. Two examples are reported with the aim of elucidating the reasoning carried out by the specialists to indicate the extent of the k_{ij} indexes. For instance, the *link with the apparel sector* (CR2) is determined just by the expected capability of the model designer to catch the tendencies taking place in the clothing industry;

Table 5.3 Correlation coefficients pertaining the link among the phases of the business process and the customer requirements to be fulfilled

CR Phase	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A11	0	1	0	0	0	0	0	0	0	0	0.7	0	0.7	0
A12	0	0	0.2	0.2	0	0.2	0	0.2	0	0	0.05	0	0	0
A13	0.1	0	0.2	0	0	0	0	0	0	0	0.25	0.4	0	0
A21	0	0	0	0	0	0	0	0	0.05	0	0	0	0.15	0.5
A22	0	0	0	0	0	0	0	0	0.1	0	0	0	0.15	0.5
A31	0.5	0	0	0	0	0	0.6	0	0.5	0	0	0.4	0	0
A32	0	0	0	0	0.6	0	0	0	0	0.6	0	0	0	0
A33	0	0	0	0	0.2	0.1	0	0.1	0	0.2	0	0	0	0
A34	0	0	0	0	0.2	0	0	0.1	0	0.2	0	0	0	0
A35	0.1	0	0.3	0.4	0	0.3	0.2	0.1	0	0	0	0.1	0	0
A36	0.3	0	0.3	0.4	0	0.4	0.2	0.5	0.05	0	0	0.1	0	0
A37	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0

as a consequence the *style determination* phase (A1) is completely in charge of the fulfillment of such requirement and $k_{CR2-A11}$ assumes the value 1. Conversely, the CR9, i.e. *care in the order dispatching*, is influenced by manifold factors intervening along the business process. At first, in order to pursue the correctness of the order, the personnel employed in the selling stages has to carefully record and communicate the details related to the job (quantities, typologies, colors, further finishes, etc.); phases A21 and A22 (at a greater extent due to the bigger number of negotiations) are then relevant for the CR9. A major contribution to the display of such customer requirement is provided by the phase A31, aimed at organizing the whole production process, planning the sequence of purchases and the manufacturing activities, checking and updating the job status for each customer. The manufacturing (A36) is responsible for the care dedicated to the orders, in terms of respecting the assigned specifications. At last, the finalization of the orders takes place in the last phase (A37), whereas any mistake can be revealed, giving rise to further re-scheduling of the wrong jobs and re-working of the flawed items. The correlation coefficients related to CR9, as resulting from the above discourse, are showed in the pertaining column of Table 5.3, which summarizes all the fractions addressed to each phase in ensuring the achievement of the customer requirements, i.e. the k_{ij} indexes.

5.3.1.3 Product Modeling

The identification of the process bottlenecks affecting the delivery of value is performed on the basis of the phases' contribution in generating the satisfaction and in avoiding the dissatisfaction of the customer. Therefore, beyond the assessment of the relevancies in impacting the perceived value, also the classification of the customer requirements according to the Kano model has been carried out, as foreseen for the second class of reengineering problems. Due to the lack of recent

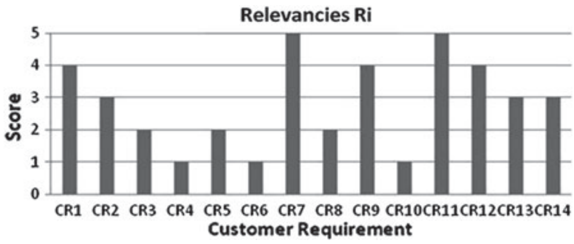

Fig. 5.7 Relevancies of the customer requirements in determining the perceived value

and reliable customer surveys, the product modeling task has been carried out by employing the opinions and the evaluation of the sector experts.

The specialists have suggested, on the basis of a 1–5 Likert scale, the degrees of relevance summarized in the diagram of Fig. 5.7.

As shown, the possibility to operate the customization of the product (CR1) in addition to the completeness of the shoe in terms of components and accessories (CR7), the attention in fulfilling the order (CR9), the aesthetic features characterizing the style (CR11) and the availability of different colors and materials (CR12), are the characteristics having the major impact on the perceived value.

The classification of the customer requirements according to the Kano model has been performed by fostering the experts reflections by means of the algorithm suggested in Chap. 3.2.3.2. Hereinafter, an example is provided with the aim of clarifying its application.

Let's consider the CR1—Customization possibility, the following question has been submitted to the experts:

Does the improper fulfillment of the Customization possibility provoke customer dissatisfaction?

They answered "No", since it has been deemed that such characteristic is not expected by the end-user when planning to buy new shoes. Therefore, according to the flow of questions foreseen in the sequence, the experts were further consulted about the following issue:

Does the correct accomplishment of the Customization possibility contribute to customer perceived satisfaction?

The possibility to customize certain details of the shoes has been considered as an unspoken feature impacting positively the satisfaction of the customer; thus they answered "Yes" to the question. According to the response, the CR1 has been classified as an *Attractive* characteristic.

The classification algorithm, applied together with the sector experts, brought to the categorization of the customer requirements, as shown in Table 5.4.

5.3.2 Problem to Ideal Solution

In this section, the determination of the value indexes characterizing each process phase is presented. Thanks to the correlation coefficients, the calculation of the contribution of each phase in generating the customer satisfaction and in avoiding

Table 5.4 Classification of the customer requirements according the Kano model

Customer requirement	Kano category
CR1	Attractive
CR2	Attractive
CR3	Must-be
CR4	Must-be
CR5	Must-be
CR6	Must-be
CR7	Must-be
CR8	Must-be
CR9	Must-be
CR10	One-dimensional
CR11	One-dimensional
CR12	One-dimensional
CR13	Attractive
CR14	One-dimensional

the customer dissatisfaction has been carried out. The resources consumption index expressing the amount of resources involved by each phase has been evaluated. Subsequently, the Overall Value, the Value for Exciting requirements and the Value for Needed requirements have been assessed giving rise to the identification of the required reengineering actions.

5.3.2.1 Phase Overall Satisfaction

The assessment of the contribution of each process segment to the customer satisfaction arises as the mathematical formulas introduced in Chap. 3.3.1.3 are applied. The previously collected indexes allow the determination of the *Customer Satisfaction* (CS) and *Customer Dissatisfaction* (CD), according to the followed expressions, here reported for the sake of simplicity:

$$CS_i = \frac{o_i + a_i}{A + O + M}; \; CD_i = -\frac{m_i + o_i}{A + O + M}.$$

The resulting values are summarized in the Table 5.5.

Subsequently, thanks to the correlations coefficients expressing the relationships between each phase and customer requirement, the contribution of each process segment in determining the customer satisfaction and in avoiding the dissatisfaction, has been calculated by means of the following relations:

$$PCS_j = \sum_i k_{ij} \times CS_i; \; PCD_j = \sum_i k_{ij} \times CD_i$$

Table 5.5 Customer satisfaction and dissatisfaction coefficients assessed for each customer requirement

CR	Kano category	a_i	o_i	m_i	CS_i	CD_i
CR1	Attractive	4	0	0	0.10	0.00
CR2	Attractive	3	0	0	0.08	0.00
CR3	Must-be	0	0	2	0.00	−0.05
CR4	Must-be	0	0	1	0.00	−0.03
CR5	Must-be	0	0	2	0.00	−0.05
CR6	Must-be	0	0	1	0.00	−0.03
CR7	Must-be	0	0	5	0.00	−0.13
CR8	Must-be	0	0	2	0.00	−0.05
CR9	Must-be	0	0	4	0.00	−0.10
CR10	One-dimensional	0	1	0	0.03	−0.03
CR11	One-dimensional	0	5	0	0.13	−0.13
CR12	One-dimensional	0	4	0	0.10	−0.10
CR13	Attractive	3	0	0	0.08	0.00
CR14	One-dimensional	0	3	0	0.08	−0.08

Table 5.6 Phase contributions in determining the overall satisfaction

Phase	PCS_j	PCD_j	POS_j	$POS_j(\%)$
A11	0.22	−0.09	0.12	16.90
A12	0.01	−0.04	0.03	4.23
A13	0.08	−0.08	0.08	11.27
A21	0.05	−0.04	0.04	5.63
A22	0.05	−0.05	0.05	7.04
A31	0.09	−0.17	0.15	21.13
A32	0.02	−0.05	0.04	5.63
A33	0.01	−0.02	0.02	2.82
A34	0.01	−0.02	0.02	2.82
A35	0.02	−0.07	0.06	8.45
A36	0.04	−0.10	0.08	11.27
A37	0.00	−0.03	0.02	2.82

Hence, the overall satisfaction generated by each process segment has been assessed through:

$$POS_j = 0.29 \times PCS_j - 0.04 \times PCS_j^2 - 0.72 \times PCD_j + 0.07 \times PCD_j^2$$

The obtained results are shown in Table 5.6. Two main phases stand out as crucial in giving rise to the customer contentment, i.e. the Style determination (A11) and the Manufacturing preparation and purchasing planning (A31). Conversely, all the other phases have a consistently lower impact on the overall satisfaction.

5.3.2.2 Resources Consumption

The criticalities of the considered business process essentially depend on issues related to the required time to supply the finished product and to the expenditures occurring to acquire the needed resources. The experts have stated a similar influence of time and cost factors with regards to the role played to the detriment of the sector competitiveness. Along the display of the industrial process, the emergence of harmful functions is conversely limited (e.g. the machinery presents rare failures) and the sensitivity is poor for the competing problems with respect to such undesired effects. Such an evidence suggests to neglect the arising unwanted phenomena in the computation of the Resources consumption index, calculated with respect to a summer seasonal collection of shoes.

The latter, according to the above considerations, has been calculated by summing up the shares of costs and elapsed times related to each process segment, by means of the following formula:

$$RES_j = C_j + T_j.$$

The terms C_j and T_j represent the portion of costs and times accounted to the phases with respect to the whole expenditure and duration of the business process. They are computed as follows, giving rise to the values summarized in Table 5.7:

$$\textit{Cost rate of j-th Phase} = \frac{\textit{Costs of the j-th Phase}}{\sum_{j=1}^{N} \textit{Phase costs}}$$

$$\textit{Time rate of the j-th Phase} = \frac{\textit{Elapsed time of the j-th Phase}}{\sum_{j=1}^{N} \textit{Elapsed times of the Phase}}$$

More specifically, in order to determine the illustrated extents, the costs have included the consideration of acquired materials, labor, auxiliary operations, energy, amortization of the machinery, management of the firm. The computation of the expenditures has disregarded the costs ascribable to real estates, given the poor contribution in the overall amount of costs. The duration of the phases has considered the period of time elapsed between the beginning and the conclusion of the involved activities. Such choice has thus allowed to take into account dead times and the actual influence of the phases in delaying the supply of the products to the retailers, hence the loss of the fashion content of the shoes, as well as the consequent risks.

As shown by the outcomes, the Manufacturing (A36) and Purchases and supply (A35) phases involve a high consumption of resources. Although at a smaller

Table 5.7 Resources consumption index of each process phase

Phase	Name	Cost rate	Time rate	RES_j	$RES_j(\%)$
A11	Style determination	0.01	0.06	0.07	3.48
A12	Collection modelling	0.02	0.05	0.07	3.48
A13	Prototyping and first industrialization	0.02	0.05	0.07	3.48
A21	Price determination and participation to the sector fairs	0.01	0.03	0.04	1.99
A22	Selling through agents; delayed orders and replenishments	0.09	0.06	0.15	7.46
A31	Manufacturing preparation and purchasing planning	0.03	0.17	0.20	9.95
A32	Size development	0.00	0.09	0.09	4.48
A33	Shoe lasts stock production	0.01	0.03	0.04	1.99
A34	Dies production	0.02	0.09	0.11	5.47
A35	Purchases and supply	0.36	0.15	0.51	25.37
A36	Manufacturing	0.42	0.15	0.57	28.36
A37	Controls and shipment	0.01	0.08	0.09	4.48

degree, also A22, A31 and A34 present a not negligible commitment of times and costs, whilst the remaining phases result definitively less expensive.

5.3.2.3 Overall Value and VAC Diagram

Through the relationships presented in the previous Chapter (3.3.1.4–3.3.1.5), the value indexes that express the phases' performance compared with the employed resources have been calculated.

The global efficiency of the phases is evaluated by the means of the *Overall Value* (OV) and additional information about the process segments are obtained through the *Value for Exciting requirements* (VE) and *Value for Needed requirements* (VN). The last two mentioned indexes point out the phases' contribution to achieve delighting and basic product properties, respectively. All the recalled parameters employed for the value assessment are summarized in Table 5.8.

Finally, Fig. 5.8 shows the *POS versus RES Assessment Chart* (PRAC), which compares the scores of the provided satisfaction and of the global resource channeling. The *Value Assessment Chart* (VAC), reported in Fig. 5.9, has been the basis for the following discussion about the reengineering priorities. Being the number of the phases quite restricted, the means of VE and VN coefficients (both around 0.6) have been chosen to discriminate between low and high values and, therefore, to subdivide the diagram into the four performance areas. In Fig. 5.10 the low performance area is zoomed.

The Overall Value index shows that the main critical issues concern the phases dealing with the manufacturing, the supply chain and the working tools production. These phases, that take place after the engineering of the collection, represent bottlenecks in the value chain creation process, showing a growth in the employed resources.

Table 5.8 Value indexes characterizing the shoes manufacturing process

Phase	Name	OV	VE	VN
A11	Style determination	1.88	3.26	1.33
A12	Collection modelling	1.25	1.23	1.23
A13	Prototyping and first industrialization	1.24	1.35	1.17
A21	Price determination and participation to the sector fairs	0.73	0.45	0.82
A22	Selling through agents; delayed orders and replenishments	0.43	0.12	0.54
A31	Manufacturing preparation and purchasing planning	0.43	0.09	0.55
A32	Size development	0.41	0.16	0.49
A33	Shoe lasts stock production	0.32	0.32	0.31
A34	Dies production	0.24	0.00	0.33
A35	Purchases and supply	0.15	0.07	0.17
A36	Manufacturing	0.14	0.04	0.18
A37	Controls and shipment	0.12	0.04	0.14

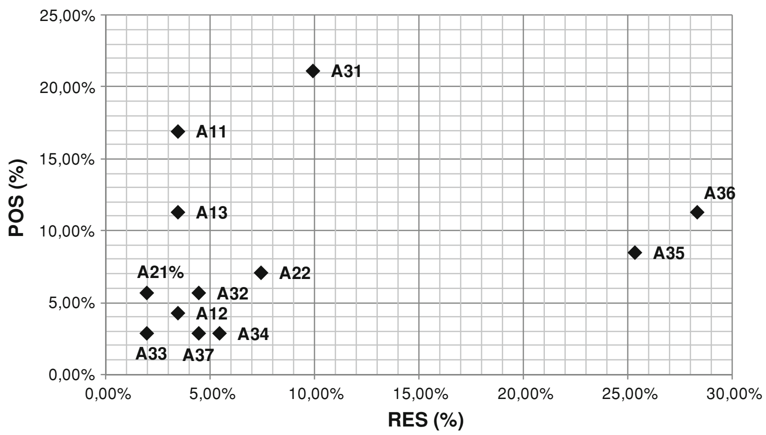

Fig. 5.8 The PRAC diagram which compares the provided overall satisfaction with the global resource channeling

The charts of Figs. 5.8 and 5.9 show that several phases belong to the low performance area. Conversely, few phases are tailored to ensure both the basic properties and those product attributes which are unexpected and generate a higher level of customer value.

The phase aims at defining the style of the shoes line is marked by High Value, but the fulfillment of exciting features is strongly predominant. Only manufacturing preparation and purchasing planning phases belong to the Basic Value area; this stage is mainly constituted by management activities and control operations aimed at dispatching correctly the orders. Among the phases in Low Value area, the ones with the worst value indexes are characterized by prevalent orientation towards the necessary features and by large resources utilization; the dies production process shows even limited benefits.

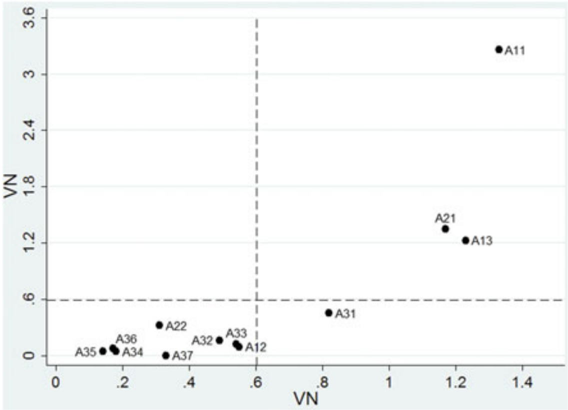

Fig. 5.9 Value assessment chart of the process built through VE and VN coefficients. The four performance areas have been identified through the average values of the indexes (around 0.6)

As a consequence, on the basis of the meaning attributed to the four value areas, the following evidences about the business process have emerged:

(1) the phases belonging to High and Basic Value areas (A11, A13, A21 and A31) have to be safeguarded, therefore they do not require substantial changes;
(2) the position of the phases A12, A32 and A33 is doubtful, straddling the low and basic benefits areas; in each case, notwithstanding their low value, these operations are not the ones requiring the greatest attention;
(3) the phase A34 regarding dies production and showing very low benefits and a not negligible consumption of resources, is worth to be trimmed or however to be submitted to major technological changes;
(4) the phase A37 concerning controls and shipment, shows the lowest share in the attainment of customer satisfaction and it is marked by the worst OV index, although contributing not marginally to the determination of expected product features;
(5) the phase A22, selling through agents, is situated in the centre of the Low Value area and it is the only one showing the opportunities to jump in the region of Exciting Value;
(6) the phases A35 and A36, concerning the purchases and the manufacturing activities, belong to the Low Value area; besides showing a meaningful contribution to pursue the basic product features, the reason of the unsatisfying performances resides in the high score of resources consumption (as remarked in Fig. 5.8), thus the reengineering actions should be oriented towards time and money savings;
(7) no phase is currently situated in the Attractive Value region and there's a need to investigate the emerging trends and the successful issues in the footwear sector, thus leading to revise the business process phases or even to add new ones.

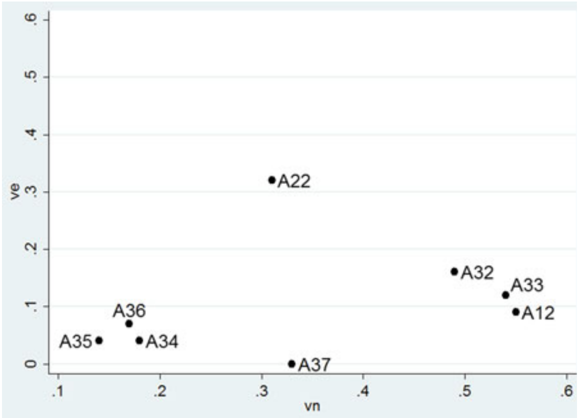

Fig. 5.10 The low performance area of the Value Assessment Chart

5.3.3 Ideal Solution to Physical Solution

The main implications of the analysis consist in the adoption of reengineering measures pertaining both the whole process and single phases. On the one hand, the poor performance of complex and basilar process segments, involving the supply and the manufacturing of the materials, determines the need to advance consistent redesign efforts, especially with the aim of reducing the resources consumption. Besides, the lack of efficient phases specifically tailored to deliver delighting product features suggests the individuation of new attributes. On the other hand, several bottlenecks affecting the process emerge as a result of the study of the business process according to value terms. The analysis of the criticalities performed through the OV index and the VAC diagram advocates prioritizing the reengineering efforts on the phases A34 and A37, beyond the already mentioned A35 and A36, which are worth to be considered within a wider perspective. According to further insights and due to limited benefits, the examination has revealed the need to verify the opportunity to migrate the functions carried out by "dies production" and "controls and shipments" phases.

5.3.3.1 Directions for a Global Process Rethinking

As previously recalled, the extent of the phases A35 and A36, showing unsatisfying value indexes, suggests to face the reengineering problem in terms of an overall task of process redesign. The results of the investigation shed light to criticalities related to the cited process segments with reference to the treated sector; however, the complexity of the involved operations and the marked differences among the firms suggest to carry out further value analyses of the activities according to the specific purchasing and manufacturing operations. Given the constraints of the manufacturing stages, intended to fulfill the scheduled jobs, the problems of each specific firm or unit can be advantageously faced with the IPPR instruments advised for the first class of business reengineering tasks.

Nevertheless, measures to reduce the amount of channeled resources could result strongly beneficial, regardless the peculiarities of each enterprise. Upstream activities, such as the organization of the production, operate in order to minimize the costs of the raw materials and of the semi-finished items. In each case, such issue does not result sufficient to align the spent resources to the generation of customer satisfaction. In this sense, according to the schema proposed in Chap. 3 for the identification of suitable reengineering tools, the employment of Lean Manufacturing hints should be evaluated by the shoe factories belonging to the sectors and by the supply chain.

Besides, if any meaningful reduction cannot be pursued of the expenditures addressed to acquire raw materials and process the required components, due to the limited sphere of influence of the shoe factories, a reduction of time resources should be also considered. More specifically, the manufacturing phase is fragmented and the coordination of its inherent activities results difficult and time consuming. Major troubles take place especially when the participation of offshore outsourcers occurs, because of transportations and exponentially increasing delays in case of mistakes or flawed semi-finished goods to be reworked or remade.

The possibility to reduce time resources would allow strategic phases (primarily the discussed activities related to purchases and manufacturing) to be repositioned. In order to reach this goal, dead times have to be strongly shortened. According to the suggestions provided in the third IPPR step for process reengineering, the means of *Quick Response* strategies result the most appropriate. The implementation of the recommended measures would imply the minimization of lead times and the consequent reduction of time to market. From this perspective, the analysis of existing technologies, policies and methods provides precise indications about the actions to be taken. According to the quick response criteria, the firms can carry out the purchases of the materials with a higher supplying time (especially leather), before the sales stage and on the basis of a forecasted quantity with a safety margin; this is however possible just with the products that can be reused, recycled or reworked, unless the firm accepts high entrepreneurial risks. Besides, the engagement of offshore subcontractors should be limited in order to reduce the phase duration and to ensure the timeliness of the commitment; moreover, researches show that onshore manufacturing and the creation of domestic partnerships are more profitable for a certain share of produced items [1].

The process shortcomings related to the miss of a sufficient amount of delighting features regards the sphere of the product and could be advantageously faced by the means of IPPR tools introduced for the third class of reengineering problems. Some evidences emerging from literature sources are briefly discussed in Sect. 5.4.

5.3.3.2 Measures to Overcome Process Bottlenecks

The arising indications which regard the phases A34 and A37 suggest their suppression and the implementation of their performed functions to other portions of the process.

The search of more suitable ways for leather cutting, replacing the production of the dies, suggests the employment of CAD/CAM systems and automated machines. Such modifications would involve consistent transformations in the sizes development phase, needing to implement new technologies, allowing in addition to augment the delivered value. Similar solutions are already adopted by similar firms of the same industrial sector, not belonging to the investigated district and thus not under examination.

The process phase in charge of controls and shipments is difficult to be substituted, unless severe transformations in the organization of the business process are applied. In other industrial contexts warehousing technologies hold the capability to assist the managing of the performed functions, allowing the A37 phase to become more agile, if not completely trimmed and integrated in the manufacturing finalization.

5.4 Discussion of the Outcomes

Among the possible approaches to reverse the negative trends in the accessible fashion footwear industry, the quick response strategies are aimed at following the rapid changing market scenarios. They individuate the speed as primary competing factor for boosting the success of the enterprises, as confirmed by plenty of literature contributions and experiences. Such practices arose during the 1980s in the apparel sector [2, 3], that has first expressed the need to speed up the introduction of the produced items in the marketplace. Minor efforts have been dedicated to the adoption of quick response policies in the footwear industry, although resulting in remarkable benefits [4], especially whereas the whole supply and retailing chain has been involved.

Recently, the urge to undertake quick response strategies as a potential help for fashion shoe factories has been the focus of a project named Just In Time for Shoes (JITS). The latter, funded by Tuscany Region and coordinated by PQuadro (a consultancy society with a long lasting experience in the footwear industry) has analyzed the competitive situation of several factories belonging to the district, which was also the object of the present investigation. As emerging by the outcomes of the project, a successful application (although partial) of quick response strategy was effectively carried out by one of the examined enterprises. Such practices have been introduced by a small shoe factory that operates just in the foreign market and is specialized in the middle quality women shoes segment, although other kinds of items are produced. The production of the firm is characterized by limited lead times considering the average elapsed duration between the orders acquisition and dispatching (about 60 days, while commonly the current business process employs between 3 and 4 months), the elimination of dead times, continual replenishments, offshore outsourcing applied just for few low quality items, anticipated purchase of the leather, improved coordination of the supply chain. Thanks to these business choices, the shoe factory has not suffered the crisis in the sector and, unlike the general trend, the turnover of firm has almost doubled after the attainment of such measures.

Eventually, with reference to the attempt of identifying new attracting requirements, the main tendency in footwear industry, as documented in the literature, is related to the mass customization phenomenon. Already in the past years, a research [5] reveals that shoe consumers "are curious about the customization concept and do realize the related benefits"; moreover the potential success of customized fashion items is deliberately assessed [6, 7]. The capability of the current business process to operate the customization of few details of the shoes results insufficient, often representing a lure for the retailer, but with a limited impact on the end-user, ultimately contributing at a low extent to repurchase intentions.

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Chapter 6
Application of IPPR to the Reengineering Problems of Class 3

6.1 Introduction: Overview of the Hairstyling Sector

The application of the instruments foreseen for the third class of reengineering problems potentially leads to disruptive innovations, regardless the treated product or business. In order to preliminarily test the adopted approach, a large amount of proposals have been advanced to the authors by SMEs, academics and students showing interest for an assisted or guided generation of creative business models and ideas, leading to numerous applications. Among the bundle of case studies, the generalities of the hairdressing sector have kindled a particular interest. The choice of attributing a particular attention to such field within the endeavor of experiencing the proposed IPPR tools has leant upon the highlighting of peculiarities about the minor modifications occurring in the hairstyling world, especially from the viewpoint of the ways the business is conducted.

The industry is strongly characterized by the presence of a multitude of small-scale hairdressing outlets and a consistently lower diffusion of salon chains and franchises of big companies [1]. The largest groups are progressively, although slowly, creeping in, also thanks to the organization of internal training schools; furthermore, being deemed to represent the glamorous branch of the industry, they are accounted to determine the tendencies about style and hairdressing techniques [2]. However, the main changes that have occurred along the last decades relate to external factors and mainly to demands of customers, especially women, looking for colors and styles requiring little time for home hair care. The increasing awareness of customers about style features and the consequent emergence of more sophisticated requests have brought to the need to enhance hairdressers professionalism and communication skills [3].

The described tendencies in the industry have poorly impacted the innovation of the equipment employed in the salons. The adaptation to trends in hair fashion can be satisfied with traditional tools, resulting in a slight rate of technological innovation [2]. The overwhelming diffusion of ICT, which has resulted as a common

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Springer Series in Advanced Manufacturing, DOI: 10.1007/978-1-4471-4017-7_6,

feature for manufacturing industries and service retailers, has just marginally impacted the beauty sector, with an expected increased involvement that concerns just the booking and the management of the liaison with the customers [4]. The running innovations have therefore resulted in a negligible impact on the way hairdressers perform their main work (cutting, coloring, styling), although in face of requested outstanding capabilities. In this framework the hand-held hair dryer introduced in the past century can still be considered the main technological breakthrough [3]. The scientific literature providing insights about the working conditions in hairdressers shops is mostly dedicated to discuss the concerns about stylists health and safety of the salon environment. However, the argument has slightly impacted the innovation patterns pertaining the sector.

With these premises, the employment of reengineering tools to achieve new business opportunities in such a conservative industry has resulted a challenging task, suitable to verify whether the emerging ideas for innovation could stimulate the change also in the life of traditional hairdressing outlets. To this aim Sect. 6.2 provides additional information about the blow dryers employed in the hairdressing industry, which will be treated as an application of product reengineering with IPPR, as illustrated in Sect. 6.3. Eventually, the Chapter closes with Sect. 6.4, dedicated to discuss the outcomes emerged as a result of the application of the methodology.

6.2 Main Features of the Professional Blow Dryers

The chance to radically rethink the equipment used in the salons, given the consolidated product features and a competition based on quality/cost trade-off, leads to follow the branch of IPPR methodology treating the third class of business problems. The starting point of this activity has taken into consideration the redesign efforts dedicated to propose a new profile for a fundamental product in the hairdressing industry, i.e. the professional blow dryer. As recalled in Sect. 6.1, the most conspicuous innovation concerning such apparatus dates back to several decades ago. The development of ionic blow dryers has resulted in enhanced efficiency, without however considerably impacting hairdressers practices.

The introduction of small-sized hand-held hair dryers has fostered the diffusion of items for domestic use, which apparently present slight differences with respect to the devices employed in beauty salons. The key features of professional blow dryers stand in greater power and in the capability to perform their functions for longer times without overheating. However, given the maturity of the product technology and the presence of a wider marketplace, also the instruments for self drying at home show good, well-established and stable performances. Such items, on the basis of the consolidated main features, fit the application of methods for the measure and the maximization of customer satisfaction or any engineering model dealing with product platforms undergoing limited changes [5–7].

Hence, the collection of the fundamental features characterizing the hair dryers and markedly the devices for professional use, results in a quite easy task. An initial information gathering has been performed to obtain an overview about the most influential competing factors. It has involved the consultation of technical material available on the web and of some stylists, beyond the mentioned scientific sources. The task has resulted in the individuation of a prior set of product attributes, on which the sources have approximately converged and that can be summarized in the followings:

- design and esthetical qualities;
- cost;
- energy efficiency;
- ergonomic grip;
- peak power to speed up the hair drying;
- versatility of the temperature of the air jets;
- versatility of air speed;
- durability;
- ease of handling;
- ease of maintaining;
- ease of repairing;
- stability of performances during the use;
- avoidance of vibrations and noise;
- strength against shocks.

The investigation of the working conditions for the specific product can however support the elucidation of further (tacit or unfulfilled) customer requirements, as supported by [8].

6.3 Creating New Value Profiles Through IPPR

The present Section depicts the implementation of the tools and the procedure foreseen for the reengineering problems falling into class 3. The following subsections are dedicated to describe the sequence of activities involved in order to carry out the task, tackling the case study concerning the hair dryers employed by professional stylists.

6.3.1 Product Information Elicitation and Modeling for a Professional Blow Dryer

As Chap. 3.2.2.2 clarifies, the aim of the first activity concerns the collection of possible sources of value to be exploited in order to generate satisfaction for the buyer. In this case the customer is represented by the hair stylist or by the salon, purchasing the blow dryer for common working activities. The hairdresser represents plainly the end user of the product and thus the one directly perceiving the advantages ensuing from the usage of the device. According to the specific value chain, the benefits arising by the product usage can however involve, indirectly, the salon as a whole or its clientele.

The primary objective is thus the creation of a comprehensive *Lifecycle System Operator*. Such tool is intended to monitor the working conditions of the blow dryer, its relationships with further systems or subjects, the activities that precede or follow the display of the apparatus functions, regarding both the status of the product and the events occurring in the hairdressing shop. The results of the mapping procedure have been obtained throughout the submission of the tailored questions (as illustrated in Chap. 3.2.2.2) for the elicitation of valuable design inputs according to time and hierarchy dimensions. The queries have been administered to three volunteer respondents involved in the hairdressing field and the answers have been consequently joined in the framework of the Lifecycle System Operator, leading to the generation of the scheme reported in Table 6.1.

In order to clarify the use of the questions in the given context, we consider the environment in which the product is situated during the utilization time. The volunteers were asked to answer to the following question:

Are there any circumstances occurring during the <utilization time of the hair dryer> and concerning the <environment in which it is situated>, m *to be observed and treated, potentially resulting as inputs for a valuable design of the product*?

The answers of the consulted stylists have been collected and grouped, so to build a set of potential value sources, as in the followings:

- the suitability of the hair dryer according to the requested details for the requested hairdo, according to customer tastes and wishes;
- the presence of vibrations and noise produced by the hair dryer, which affect the surrounding environment;
- the presence of other systems within the salon such as chairs, the capes, the mirrors and, more in general, the furniture and other accessories;
- the presence of other customers within the saloon;
- the hot air produced by the hair dryer mistakenly directed to not haired surfaces of the customer body.

The collected sources of value have been then used to elicit the product attributes, which can plausibly contribute to determine the customer appreciation. The emerging sample of attributes has to be integrated with the already present (and overlapping) set of established features, that have been listed in Sect. 6.2, as a direct result of the preliminary product investigation, which were aimed at gathering the prior information about the blow dryers.

The questioning techniques proposed in Chap. 3.2.3.3 allow furthermore to determine the appropriate functional features related to the set of attributes. Additionally, throughout the gathering of the volunteers' opinion, an evaluation has been provided about performance levels and their correspondence with actual customer demands. To the purpose of clarifying the way of performing the classification of the attributes, let's take into consideration the following example. If the user of IPPR wants to classify the CR1—"Design and esthetical qualities", he/she must ask himself/herself and the stylists:

Table 6.1 Lifecycle system operator for a professional blow dryer

	Purchasing, choice and access activities	Before use operations	Utilization time	Elapsed time before further exploitations	End of the functioning
Environment in which the product is situated	Service for transportation; Installation; Training	Stylist; Decision about the hairdo; Salon, chairs, capes and mirrors; Other customers being served or waiting	Use suitable for the stylist; Vibrations and noise; Salon, chairs, capes and mirrors; Customer (and further details of the hairdo); Other customers being served or waiting to be served (sitting, reading magazines, talking); Very hot jets of air towards not haired surfaces of the customer	Customer check about the result (i.e. mirroring the nape or the back); Cleaning floor; Chairs, capes, mirrors and towels; Hair health; Stylist health	Salon renovating
Product or service level	Cost; Efficiency, durability and main features; Design and esthetical qualities	Hair washing; Hair cutting; Hair dying	Hair drying and styling (with pauses for hair brushing); Combined use with hairbrush; Controllability and versatility of the hair drying (amount of water, hair length, hairstyle, hair color, kind of hair); Use of energy; Blow dryer wire and connection to a fixed surface; Alternative employment of straighteners, curling wands	Storing; Tidying up; Reducing temperature; Maintaining; Repairing	Disposing; Recycling; Reusing in other environments; Reusing with further damaged parts
Parts, components and accessories	Components		Components during use	Components after use; Refilling	Disposed materials

if we consider the <Design and esthetical qualities>, are we dealing with the endeavor to request the customer less money, time, energy, space, tools, materials, information, experience or know-how?

The aesthetic characteristics are properties which have not any impact on the resources consumption of the customer, therefore the answer is negative. Hence, the following question arises, as suggested by the procedure:

if we consider the <Design and esthetical qualities>, are we dealing with the objective of reducing the impact of an undesired event, generally associated with the product functioning or decrementing the probability of such unwanted situation?

Once again the answer is negative since the considered feature is not related to the mitigation or elimination of damages or bad consequences that the customer can undergo, in a direct or indirect way, due to the hair dryer. Thus, the user must answer to the last question:

if we consider the <Design and esthetical qualities>, are we dealing with the effort of increasing the benefits for the customer or for a circumscribed group of users, the versatility of the product functioning, the stability of the outcomes, the delight generated by the treated system?

A pleasant aspect of the product is a property which aims at delighting the user. These considerations allow to answer affirmatively the question, thus the "Design and esthetical qualities" can be suitably classified as an attribute characterized by the "UF" functional features.

Further on, the analysis of the present hair dryers reveals a certain care towards the aesthetics; however, with regards to the fashion environment in which the devices are situated enhancements would be welcomed. Therefore, the offering level of this attribute can be assessed as moderate and barely sufficient to satisfy the present demand of the customer.

Since the value profiles of professional blow dryers do not differ considerably, the framework reported in Table 6.2 has been deemed sufficient to map the main aspects about the market of the devices under investigation. The Table reports the monitored product attributes, whereas the first 14 items are directly related to the competing factors listed in Sect. 6.2, while the others have been obtained by focusing the attention on the value sources mapped through the Lifecycle System Operator.

The procedure allows to point out, beyond the functional features relevant for the fulfillment of the next task, those attributes which result missing or unsatisfied, viable to indicate interesting business opportunities regardless the employment of IPPR suggested tools. Besides, the big quantity of product attributes, as listed in Table 6.2, shows a noticeable amount of differentiation opportunities for the investigated industry. Thus, several new product profiles can be generated through the employment of the suggested guidelines.

Table 6.2 Product attributes emerging from the product analysis

CR#	Product attribute	Functional feature	Performance and customer demand
1	Design and esthetical qualities	UF	Moderate, barely sufficient
2	Cheapness of the device	RES	Good, adequate
3	Energy efficiency	RES	Moderate, unsatisfying
4	Maneuverability, due to ergonomic grip	RES	Good, adequate
5	Hair drying speed (due to peak power)	RES	Good, often outstripping the demand
6	Versatility of the temperature of the air jets	UF	Very high, outstripping the demand
7	Versatility of air speed	UF	Good, adequate
8	Durability of the device (along the time)	UF	Good, barely sufficient
9	Avoidance of slipping from the hands	RES	Moderate, unsatisfying
10	Ease of maintaining	RES	Low, unsatisfying
11	Ease of repairing	RES	Low, unsatisfying
12	Stability of the performances during the use	UF	Very high, adequate
13	Avoidance of vibrations and noise	HF	Low, unsatisfying
14	Strength against shocks	HF	Moderate, adequate
15	Ease of installation	RES	Very high, adequate
16	Limitation of needed training	RES	Very high, adequate
17	Provided support along the operations preceding the styling	UF	Absent, unsatisfying
18	Reduced encumbrance	RES	Moderate, unsatisfying
19	Avoidance of overheating during use	HF	Good, barely sufficient
20	Controllability of the air jet direction	UF	Good, barely sufficient
21	Avoidance of heating not haired human skin	HF	Absent, unsatisfying
22	Limitation of noise, silentness	HF	Moderate, unsatisfying
23	Limitation of vibrations	HF	Good, adequate
24	Versatility in accomplishing variable customer requests about the hairdo	UF	Moderate, unsatisfying
25	Versatility in treating various kinds of hair	UF	Low, unsatisfying
26	Possibility to be replaced with alternative instruments	UF	High, adequate
27	Freedom of use, maneuverability (due to external boundaries, i.e. electrical wire, hairbrush)	RES	Low, unsatisfying
28	Aesthetical matching with salon equipment	UF	Absent, unsatisfying
29	Functional matching with salon equipment	UF	Absent, unsatisfying

(continued)

Table 6.2 (continued)

CR#	Product attribute	Functional feature	Performance and customer demand
30	Controllability of the on/off functions	UF	Good, barely sufficient
31	Limitation of energy consumption due to unintended use	RES	Low, unsatisfying
32	Customizability	UF	Absent, unsatisfying
33	Versatility of the device according to stylist's experience and individual characteristics	UF	Low, unsatisfying
34	Possibility of integrating accessories	UF	Moderate, unsatisfying
35	Possibility of replacing damaged components	UF	Moderate, unsatisfying
36	Ease of replacing damaged components	RES	Low, unsatisfying
37	Limitation of the probability of experiencing damages along pauses of use	HF	Good, adequate
38	Limitation of hurdling activities in the salon along pauses of use	HF	Good, adequate
39	Ease of maintenance	RES	Good, adequate
40	Cheapness of maintenance	RES	Low, unsatisfying
41	Safety (e.g. limitation of carpal tunnel)	HF	Low, unsatisfying
42	Capability to blow away cut hair	UF	Good, adequate
43	Possibility to be reused after the failure	UF	Low, unsatisfying
44	Reusability of the components	UF	Absent, unsatisfying
45	Recyclability	UF	Moderate, barely sufficient
46	Reusability in event of salon changing or renovating	UF	High, adequate
47	Environmental sustainability	HF	Moderate, barely sufficient

6.3.2 Building a New Profile and a Preliminary Conceptual Idea for a Professional Blow Dryer

The present Section shows the application of the proposed IPPR tools to generate a feasible original profile for the investigated case study. According to the iterative redesign process illustrated in Chap. 3.3.2, the task has to be fulfilled by alternatively employing methods and techniques relevant for both the steps 2 and 3 of the overall methodology, as structured for the third class of reengineering problems.

By following the footprints of the recalled cyclical roadmap, the first recommended stage is the individuation of priority objectives to be pursued through the product rethinking. In coherence with the indications provided by the New Value Proposition Guidelines (NVPGs) and with the need to act on insufficient performances, the main endeavor has been addressed towards the attainment of a more practical employment of the blow dryer (improvements about the CR27, classified as RES) and reduction of health related side effects (enhancements regarding the CR41, clustered as HF). The goals are somehow related, since an increased ease of handling could allow to reduce drawbacks concerning the emergence of muscular problems on stylists, such as the carpal tunnel syndrome, to which the weight of the blow dryer contributes. The twofold scope can be accomplished by introducing solutions that do not require the front wire, a relevant hurdle for gaining a suitable maneuverability, and characterized by a low weight of the apparatus.

The presence of a limited bundle of attributes to be analyzed has allowed the immediate identification of the related engineering requirements and design choices. The employment of the Quality Function Deployment, suggested in the workflow of the methodology, can be skipped with regards to the presented case study.

Subsequently IPPR recommends to delineate how to implement the previous advantages. In order to increment the lightness of the device, a traditional design approach would head towards a trade-off between the weight of the engine and the power of the apparatus. The latter engineering feature determines the speed of drying (CR5, RES), a sometimes oversupplied characteristic that is however better not to be jeopardized, especially because of the indications emerging in the NVPGs. As an alternative, cordless battery blow dryers could be proposed, but their performances do not fit the exigencies of hairdressing applications.

The overcoming of the contradiction between mutually not compatible demands (lightness and power) requires proper techniques leading to valuable conceptual solutions. In such situations, TRIZ, as highlighted in Chap. 3.4.2, includes the most helpful body of knowledge.

For instance, by exploiting inventive and/or separation principles, the resolution of the conflict heads to concepts aimed at disconnecting the components of the hair dryer. Indeed, the element performing the main useful function of the apparatus, i.e. the tube conveying and directing a hot flow, can be separated by the fan addressed at providing the requested properties of the air (by heating and accelerating it). The transformation pattern can be supported by rearranging the collocation of the device (and of its parts) inside the salon. The displacement of the blow dryer motor into elements belonging to the salon environment has been thus evaluated, individuating two possible solution concepts. The options regard the integration of a body including the engine within the roof or the salon chair, with the consequent handling of a flexible tube to be easily moved and directed by the stylist. The ideas could be roughly depicted by positioning a hairdryer suite, like those commonly employed in the locker rooms of sports facilities, in the intended points of the shop, like sketched in Figs. 6.1 (for the roof) and 6.2 (for the salon chair). The rough concepts require undoubtedly a proper sizing of the tube length and a suitable design of the sensing mechanism capable to activate the requested flowing of hot air. Nevertheless no sophisticated technology is expected to be required in order to implement the presented ideas.

At a first glance, the thought solutions could be relevant for all the stylists, given the diffusion of muscular diseases due to the employment of hairdressing tools. Moreover, the elimination of the front wire can represent a benefit per se, given the consequent nuisance arising as the dryer is handled and sometimes moved in front of the customer. However it is deemed that less powerful hairdresser could perceive the greatest advantages.

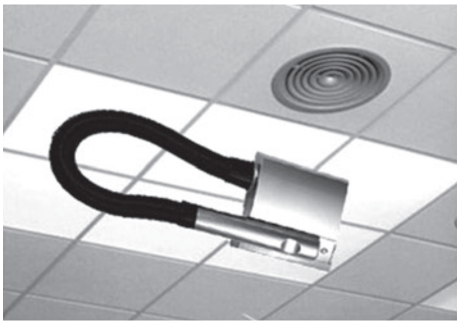

Fig. 6.1 Sketch of the integration of the hair dryer below the salon roof

The following step to be run regards the identification of possible additional benefits or potential drawbacks, emerging as the development is carried out of the ideas kept in the "rough copy" of the project.

In the first case (roof implementation of an engine feeding one or a plurality of blow dryers in the salon), the distance of the motor would result in a diminished noise, if the area occupied by the stylists and the customers is considered. The decrement of noise, thus the application of the Raise action for the CR22, would result in a further considerable advantage, according to the NVPGs and the general criteria concerning the employment of the FAF. On the other hand, in the second option (salon chairs equipped by a component, resembling a typical wall hairdryer suite), the presence of the engine in the surroundings of the working space would not considerably impact the silentness of the environment. Thus, in order to provide a major noise restraint, the peak power of the blow dryer should be significantly limited. This means to resort therefore to the action Reduce CR5 (RES), about which we have already warned out, due to the infringement of the NPVGs.

In both the cases, the presence of flexible tubes favors the introduction of a control mechanism meant to automatically and quickly stop the air jets when unneeded. Such control could be operated by the stylist with simpler movements of the hands and the fingers, e.g. by releasing the tube. This measure would positively impact the controllability of the air jet, leading to the action Raise CR30 (UF), moderately impacting the success of a NVP, according to the guidelines.

The foreshadowed pair of conceptual solutions would allow even an integrated functional design of a set of salon equipment and accessories. The consequent action, Create CR28 (UF) is complaint with the advantageous measures foreseen within the grid of NVPGs.

The main drawback of the design concepts could result in a more difficult regulation of the temperature ranges, whereas such function is allowed by directly operating the buttons on common blow dryers. The resulting measure (Reduce CR6, UF) is allowed by the general rules for the application of the FAF and is meant to cause limited bad consequences with respect to the guidelines.

Furthermore, the possibility to use special hair drying and styling tools, that sometimes replace the traditional hair dryers (e.g. straighteners, curling wands), would be completely jeopardized, if not through their common connection to the

Fig. 6.2 Sketch of the implementation of the hair dryer within the salon chair

plug. The additional action to be considered (Eliminate CR26, UF) is not consonant with the scope of the FAF, being such attribute not oversupplied, but does not represent a particular source of harm with regards to the proposed guidelines.

Other features could be automatically impacted by the design of the novel product profile, but at a marginal level. For example, the possibility to easily switch off the hair dryer could bring improvements in terms of reducing energy consumption, avoiding to generate hot air in the short periods it is not needed and the device is not turned off for the sake of convenience, e.g. when the hairdresser moves around the customer to be styled. Additionally the same conditions could result in negligibly less probable events of directing hot air towards the skin of the salon visitor. In absence of consistent value shifts according to these features, no action is considered highlighting such advantages.

On the basis of the followed redesign procedure, Table 6.3 summarizes the actions that would result in the NVP task, whereas the fifth one, reported in italics, concerns just the solution involving the integration of the blow dryer and the salon chair. According to the depicted transformation of the product profile, the number of value-adding measures is higher than the occurrences of Reduce and Eliminate actions, especially for the roof solution. At the same time the infringement of the guidelines involves just partially the option of the joining of the treated device with the chair. The team formulating the present NVP strategy has deemed the results satisfying for the verification and the consequent further development of the profile. Therefore, no additional cycle of the roadmap procedure described in Chap. 3.3.2 has been performed.

6.4 Survey and Discussion of the Results

In order to assess the appreciation of professionals about the new generated profiles, and potentially the differences between the alternatives, a suitable questionnaire was submitted by email to some randomly identified hairdressing shops and beauty salons. The authors received 30 replies, among which some of them resulted incomplete. The main outcomes can be summarized as follows:

Table 6.3 New value propositions for a professional blow dryer

Action	Functional feature	Product attribute
1. Create	UF	CR28 Aesthetical matching with salon equipment
2. Raise	UF	CR30 Controllability of the on/off functions
3. Raise	HF	CR22 Limitation of noise, silentness
4. Raise	RES	CR27 Freedom of use, maneuverability (due to external boundaries, i.e. electrical wire, hairbrush)
5. Reduce	RES	CR5 Hair drying speed (due to peak power)
6. Reduce	UF	CR6 Versatility of the temperature of the air jets
7. Eliminate	UF	CR26 Possibility to be replaced with alternative instruments

- the enhancements with respect to common blow dryers result effectively as a considerable benefit according to the opinion of 27 respondents out of 29;
- 22 stylists out of 26 would take into account the advantages shown by the presented hypothetical products, when choosing the equipment and the furniture for a new or renovated salon;
- according to 20 answers out of 26, it is affirmed that similar products could be likely to be launched in the marketplace in the next future;
- however, just 12 hairdressers out of 26 would tolerate the drop of the hair dryer performances in terms of peak power.

The results of the test confirm the attractiveness of value profiles that follow the guidelines emerged by the presented research. On the contrary, the infringement of some of them, such as the increase of resources consumption in terms of time within the analyzed case study, results in consistent drops in customers appraisal. In this sense, the solution concerning the displacement of the hair dryer body below the roof, results more convincing.

Insights about the motivations of the respondents, with reference to the acceptability of the reduction of the peak power, give rise to different ideas and approaches in making the business. The stylists that would easily bear such diminishment, state that the disproportionate power of the blow dryers results in exceeding temperatures, leading to ruin the hair. On the other hand, the drying speed does not result a relevant competing factors for those kinds of salons, welcoming a longer staying of the clients in the shop. The latter regards mostly small hairdressing outlets with a loyal and consolidated clientele, for which the visit to the stylist involves also spending good time and keeping social relationships. Similarly the need to serve quickly the customers is not perceived by the hairdressing shops including additional beauty treatments and spa. In such cases the long duration of the visits results as a greater arouse for the customers of the salon and an occasion for the shop holder to offer additional services. Conversely, the outlets serving customers with low amounts of available time for hair care, cannot disregard the drying power of the device and the speed in performing the styling.

As a result, the new product profile and its alternative implementations underline a segmentation of the current marketplace, according to circumstances that have not been yet fully investigated by the hairdressing industry. Such indications are widely confirmed by researches about customer loyalty, according to which age and social factors play a fundamental role in the client retention of hairdressing stores [9, 10].

Thus, the task of tackling a reengineering problem of the third class, has resulted in the individuation of a favorable direction and inspiration for the innovation of the equipment used in hairdressing salons, beyond the generation of a new product profile, worth to be further developed. In such framework we refer particularly to the solution involving the integration of the hair dryer in the surroundings of the shop roof, which best corresponds to the indications addressed by the NVPGs. Within the whole NPD cycle, existing patents represent a valuable starting point for the generation of a physical embodiment of the innovative blow dryer, e.g. [11, 12], potentially leading to provide the technical support for an enhanced business model.

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Chapter 7
Discussion and Concluding Remarks

7.1 Introduction

This Chapter is devoted to an overall discussion about IPPR with the aim of summarizing its main features, weak points which require to be overcome and results achieved during the experimentation activities.

More in particular, the purpose of Sect. 7.2 is to provide an overview of the overall achievements with respect to the methodological objectives presented in Chap. 1. With the aim of shedding light on the current priorities to attain methodological and practical improvements, the research activities carried out to develop IPPR are synthetically illustrated.

Section 7.3 briefly summarizes the results of the performed tests, focusing on the evaluated performances of the method in terms of effectiveness, robustness and repeatability, thus providing some suggestions to enhance the methodology.

7.2 IPPR: Achievements and Open Issues

The achievement of the proposed methodological objectives is hereby discussed with the aim of pointing out the attainments as well as the issues still open, which require further research efforts.

Altogether, IPPR is a decision support instrument which provides a viable aid in identifying the most appropriate approach to solve the addressed reengineering problem. The outputs supplied by the method consist in a clear and comprehensive representation of the priorities and the consequent redesign actions to be undertaken. As stated in Chap. 1, successful BPR initiatives require an exhaustive description of the process functioning in order to highlight the main deficiencies on which to concentrate the reengineering efforts. This task can be performed by using modeling techniques capable to summarize the whole set of information and

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data belonging to different domains. To this end, IPPR provides a process modeling technique which allows the collection and structuring of all the information and data related to the business process, in both technical and economical domains. The proposed model is based on the integration of different techniques such as:

- IDEF0 to represent the process activities according to the scheduled sequence, indicating involved know-how, employed technologies, control mechanisms;
- EMS to account for the flows of energy, materials and information involved in the business process;
- TOC, to represent the expenditures related to each phase of the business process.

Beyond the process modeling activity, the determination of the relevant aspects of value delivered to the customer, represents another crucial task in order to obtain meaningful feedbacks about what should be changed in the business process. Reasoning tools have been developed within IPPR to support this step, such as the Lifecycle System Operator and the CRs Checklist. These instruments are suitable means which allow a comprehensive investigation of the aspects of value ascribable to a given product. They characterize the product along the dimensions of its lifecycle and according to the functional role played by its features within the delivery of customer satisfaction.

A further original contribution of IPPR regards the extension of the Value Engineering validity beyond the classical approach which assesses the worthiness of a process through the ratio between technical performances and involved costs. Indeed, proper assessment metrics have been defined that consider the rate between the contribution of each phase in generating the customer satisfaction and the resources required to deliver such benefits.

The reengineering directions arising by the employment of IPPR for problems concerning industrial processes are oriented towards the growth of the value associated with the delivered outputs and/or with the reallocation of the resources along the sequence of the phases.

Furthermore, suitable guidelines have been defined to support new value proposition tasks oriented towards the attainment of radical innovations for products and services. Such guidelines have been extrapolated thanks to a deep analysis of dozens of success stories and represent a complementary tool to strengthen the application of the Four Action Framework.

The developed tools to guide the redesign of product platforms is a consistent aid also within the field of Product Service Systems. The generation of new product profiles can include the introduction of a major servicing, thus disclosing when such measure could result suitable for providing enhanced customer value.

Despite the consistency of the above summarized achievements, IPPR requires further developments, aimed at primarily improving its systematic degree. Some of these issues are already addressed in ongoing research activities.

Among the various criticalities, the identification of the right level of detail at which to deepen the modeling activities is still an essential issue to be addressed.

With reference to process reengineering, the quantity of the phases to be investigated can influence the identification of the relevant process bottlenecks, which represents a key step in IPPR. Therefore, the definition of more precise rules aimed at supporting the user in the segmentation of the process into a meaningful number of phases according to the customer requirements to be fulfilled, is an essential development activity in order to improve the reliability of IPPR.

As widely underlined in the book, IPPR employs the value indexes as fundamental criteria for highlighting the process criticalities. Such coefficients result as a combination of factors concerning the expected delivered benefits and the costs addressed at the industry level. The evaluation of the bottlenecks through these metrics is still performed regardless of the impact on customer satisfaction resulting by fluctuations of the actual process efficiency. The latter influences indeed the offering levels pertaining the fulfilled product attributes. Thus, the integration is strongly recommended of the developed metrics with models capable to take into account also the recalled efficiency aspects, in order to strengthen the rigor of IPPR as decision support system.

Further on, with a particular emphasis on the information gathering, methodological deficiencies arise due to the disproportioned role entrusted to the knowledge of the sector experts for a wide range of analysis activities. Such tasks include the definition of the customer requirements, their relevance in determining the customer perceived value and their classification according to the Kano model. The reliability of the outputs provided by these activities can benefit from a more systematic approach in order to reduce the impact of subjective evaluations. Besides, the introduction of a model capable to manage diverging opinions about the issues investigated along the analysis of the business process, could definitely make these activities more robust.

Eventually, other research activities have been outlined to improve the potential of the guidelines for supporting NVP tasks. In such a context, the definition of a more prescriptive path as well as the enhancement of the classification of the product features, are essential activities to strengthen the application of the guidelines. A planned activity regards the fine-tune of a metric to assess the likelihood of product success, according to the followed value transition. Such an instrument, currently in its validation phase, could operate as a decision support about investments to be channeled in light of a plurality of product platforms alternatives to develop within a company.

According to the above discussion, it can be concluded that the methodological objectives have been overall attained. However, some developed tools and some application steps require further investigation in order to enhance the effectiveness of IPPR.

7.3 Reliability of IPPR

The book illustrates applications of the proposed tools to three case studies, with regards to the different classes of business problems described in Chap. 1. Beyond the step-by-step application of the methodology, Chaps. 4–6 include a final discussion enforcing the conclusions emerging as a result of IPPR employment, throughout surveys and crosschecks using literature sources. Hereby, we briefly recall the issues supporting the outcomes of the methodology.

With reference to class 1 of reengineering problems, the logic and the tools for process analysis have been proposed in the field of the solid bio-fuel production process. Starting from the analysis of the market opportunities and process needs, the application of the method has brought to identify the need of designing an innovative dewatering and grinding technology for woody biomass capable to improve the efficiency of the whole manufacturing process. The arisen indications have been widely verified through the well established and acknowledged scientific literature.

According to the second class of business problems, the method has been applied in the footwear sector bringing to the definition of suitable reengineering directions aimed at shortening the time to market in the industry of accessible fashion shoes. All the identified strategic actions comply with those successfully implemented in the sector and arisen from dedicated research projects.

With regards to class 3, the guidelines for New Value Proposition have been applied in the field of the professional hair dryers. IPPR supported the definition of new relevant product features, starting from the analysis of the customer needs and the survey of the devices currently in the marketplace. The effectiveness of the arisen indications has been verified by using the Voice of the Customer, as a means to obtain feedbacks in the prior product development stage. The results have shown that a new value profile compliant with the guidelines, meets the consensus of a not negligible segment of users (about 90%).

Beyond the application of the presented tools in different industrial domains, which are not reported in the book, tailored activities have been carried out with the aim of verifying the robustness and the repeatability of outcomes of the method. Within process reengineering tasks, a case study belonging to the pharmaceutical field has been considered for an experiment, involving a sample of MS engineering students. The example is related to established industrial practices which have been overcome and partially substituted by known process alternatives. Even if the size of the testers group was not sufficient to perform a fully acceptable validation, some interesting evidences arose. The test revealed an overall consistency with the results extracted by sector experts employing IPPR and a fundamental coherence with the redesign of the industrial activities observed in the technical evolution of the process.

Although a great amount of individual tests converge towards the results extracted by the sector experts, the sample of students provided not negligible variable outcomes, potentially leading to misleading conclusions. With respect to such condition, it is recommended to perform multiple applications of the method by different users in order to take into account a plurality of points of view within the company or the industry and to collect the gathered data. By applying statistical tools treating the diverging inputs, the end results are characterized by enhanced reliability. In order to ease the task, the authors are developing a computer aided tool to gather the evaluations of multiple analyzers and extract the most consistent process bottlenecks.

The tools for product reengineering have been subjected to wide experiments, involving academics and University students. Whereas the possibility to generate innovative product profiles still depends on individual creativity, the proposed tools have demonstrated a consistent capability in guiding the exploration of potential value adding circumstances. This results in a severely augmented capability to individuate valuable alternatives to undergo product development initiatives. Additionally, a pair of PhD students is currently in charge of the methodological development of the New Proposition Guidelines, with the objective of delivering a computerized decision support system assisting the early stages of NPD tasks.

7.4 Final Considerations

Eventually, the manifold applications of the methodology in very different contexts have demonstrated its effectiveness in identifying value bottlenecks and suitable directions for overcoming the main hurdles. The original contribution of the book, although the presented methodology will be subjected to continuous improvements, is a set of (already effective) practical suggestions to orientate reengineering initiatives in industry, instead of relying on the most convincing techniques proposed by consultants which cannot fit all the situations. The changing conditions in the marketplace and at the industry level require indeed customized tools; let's attempt to aid companies at least to choose the most suitable ones. The change is the motor of innovation, perhaps also the greatest source of risks and opportunities for the enterprises. For sure, it is the main fuel of our research activities.

Appendix A
The IDEF0 Model

The set of models belonging to the Integration Definition Function Modeling (IDEF) group refer to a family of standards for systems and functions representation developed under the aegis of the United States Air Force.

IDEF0 represents one of the most diffused models within the group of IDEF schemes and with reference to the set of methods employed to depict decisions, actions and activities. By providing the functional perspective of a given system, the representation scheme is aimed at facilitating the communication among different parties. Beyond supporting the interchange of information, the model helps the analyst in focusing on which functions are delivered by the system and what enables its working mechanism.

According to what is claimed in the registration document of the model at the American National Institute of Standards and Technology (NIST), the functional language owns the following features and capabilities:

- "Performing systems analysis and design at all levels, for systems composed of people, machines, materials, computers and information of all varieties—the entire enterprise, a system, or a subject area;
- Producing reference documentation concurrent with development to serve as a basis for integrating new systems or improving existing systems;
- Communicating among analysts, designers, users, and managers;
- allowing coalition team consensus to be achieved by shared understanding;
- Managing large and complex projects using qualitative measures of progress;
- Providing a reference architecture for enterprise analysis, information engineering and resource management" [1].

According to its formalism, IDEF0 models illustrate the relationship of all the functions in a graphical format with "box and arrows", whereas the boxes are the functions themselves and the arrows stand for the constraints and the involved flows.

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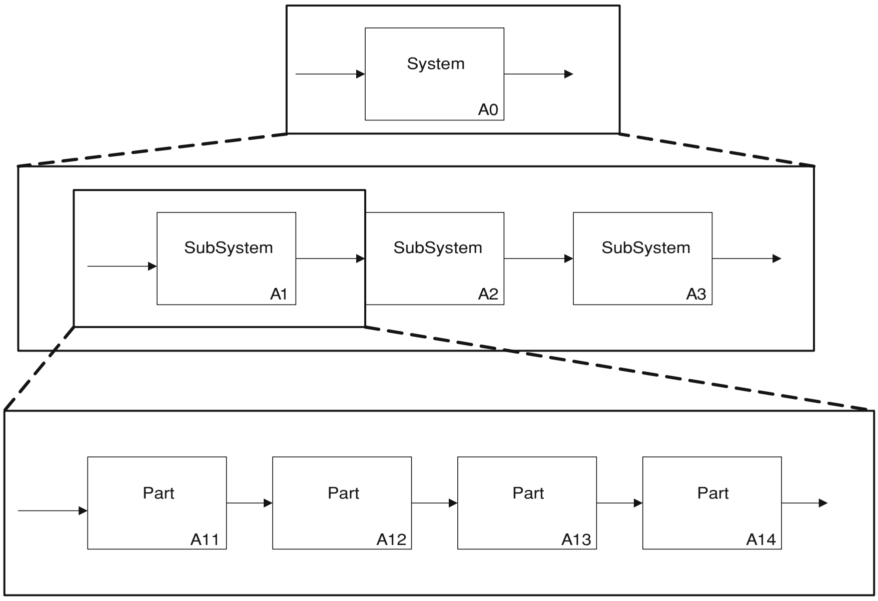

Fig. A.1 Hierarchies of systems and functions in the IDEF0 model

The description starts with a single box, standing for the representation of the overall designed system, labeled as A0. The box A0 is subsequently decomposed into a more complex diagram constituted by up to seven interconnected boxes. The hierarchical subdivision is repeated for each function of the diagram, then for each box in the resultant schemes and so on, until the system is fully described. Boxes are numbered according to the hierarchical levels, with the label being used to facilitate the comprehension of the relationships among different diagrams. For instance, the first box resulting by splitting the A0 is A1, and the third box in the decomposition of the latter is A13 [2]. Figure A.1 clarifies the decomposition process.

The flows depicted through the arrows represent manifold sorts of inputs, outputs and controlling rules. The inputs in form of materials or objects to be transformed enter the box from the left; the arrows directed towards the top of the box refer to controls, whereas those reaching the opposite side represent mechanisms and technologies. The outputs of the system exit the box from the right side (see Fig. A.2).

Although IDEF0 standard has been conceived as a functional modeling tool, it is often used even to represent processes, since the system functions that can be modeled include activities, actions, processes, operations [1].

As a result, within process modeling, IDEF0 models can be employed with a different formalization: the boxes describe the activities [3] that perform the functions and the arrows stand for the information and the objects that are interrelated in a given system [4]. Due to such common application, IDEF0 is

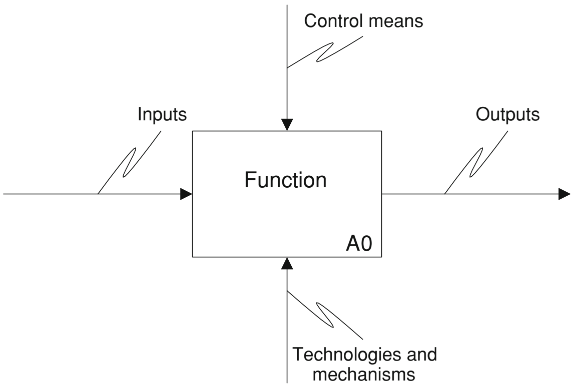

Fig. A.2 Inputs and outputs in the IDEF0 model

considered among the most useful instruments also to perform business process modeling, with the possibility to decompose the processes in lower level activities [5].

Appendix B
The EMS Model

The Energy-Material-Signal (EMS) model is a sort of black box representation to schematize functions, based mainly upon the work by Pahl and Beitz [6] and other scholars. An analysis of engineering systems reveals that they essentially channel or convert energy, material or signals to achieve a desired outcome. Energy is manifested in various forms including optical, nuclear, mechanical, electrical, etc. Materials represent matter or substances. Signals represent the physical form in which information flows. For instance, data stored on a hard drive (information) would be conveyed to the computer's processor via an electrical signal. An engineering system can therefore be initially modeled as a black-box (Fig. B.1) with energy, material and signal inputs which are modified from the system in the form of outputs. According to EMS original formalism, energy is represented by a thin line, material flows by a thick line, and signals by dotted lines as shown. The engineering system therefore provides the functional relationship between the inputs and the outputs [7]. The system can be further subdivided into sub-systems of a lower hierarchical level to better describe the involved functions and transformations.

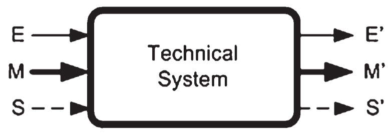

Fig. B.1 Sketch of the EMS model

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Appendix C
The Model of the Theory of Constraints (TOC)

The Theory of Constraints [8] is a management practice aimed at identifying the weak ring of a value chain, according to financial metrics.

According to the TOC, the production process is represented as a technical system constituted by chains of operations, where each ring represents a phase; in Fig. C.1 an example is provided. The flows taken into account in this kind of model are the monetary flows generated by the system that are defined as it follows [9]:

- Throughput (T): “The rate at which the entire system generates value through sales (product or service)”: this flow represents the money coming in the system.
- Inventory (I): “All the money the system invests in things it intends to sell”: this is the flow of money that is spent in order to buy raw materials.
- Operating Expenses (OE): “All the money the system spends turning Inventory into Throughput”, this flow of money going out the system to buy labor, utilities, consumable supplies, energy, etc.

With regards to the convention introduced by TOC, the throughput is the revenue coming from sales, divided by the time elapsed to carry out the manufacturing of the items.

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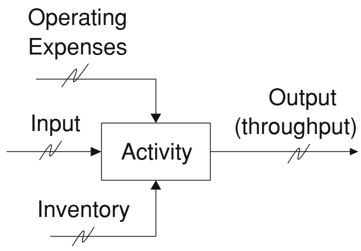

Fig. C.1 Sketch of the activities involved in an industrial process depicted through TOC formalism

As a result of the individuation of the value bottleneck, in terms of throughput metrics, the endeavors of the firm should be channeled massively to improve the least performing stage of the business. Such measure should be ceased just when another segment of the industrial process becomes the new weak ring. Still according to TOC principles, the first priority in improving the system is to increase T, since it has the greatest potential impact on the bottom line, while decreasing OE and/or I is secondary and in any case it should not result in jeopardizing future throughput [10].

Appendix D
The System Operator

System Operator or, as Genrich Altshuller (the founder of TRIZ theory) named it, Multi-screen Schema of Powerful thinking, shows the model of advanced thinking in the course of problem solving process. Learning this model and developing appropriate skills to use it in practice is a core of Altshuller's educational program [11].

The System Operator can be used with different objectives within the problem solving process. For example, during the preliminary stages, while looking for roundabout problems whose solution allows to obtain the same overall goal, a multi-screen view helps orienting the thought from cause prevention to effects compensation or mitigation, as well as a means to change the scale of the solution space in order to avoid psychological inertia. Besides, while looking for resources, the System Operator helps focusing the attention on each relevant aspect of the system and its environment, by analyzing any time stage at any detail level with a systematic approach.

System Operator could be seen as a three-dimensional parametrical space (Fig. D.1):

- Dimension of Hierarchical level of System: Whatever is the element we are taking into account (System), it is always possible to consider its constituting parts (Subsystems) as well as the environment it belongs to (Supersystem),
- Dimension of Time: whatever is the time interval taken into consideration for a certain analysis or description (Present), it must be considered as a phase of a sequence, therefore with a Past and a Future;
- Dimension of Anti-Systems: whatever is the property of an element taken into consideration, this dimension suggests looking to the opposite values of the same property (anti-property); similarly, a combination of anti-properties characterizes an anti-system.

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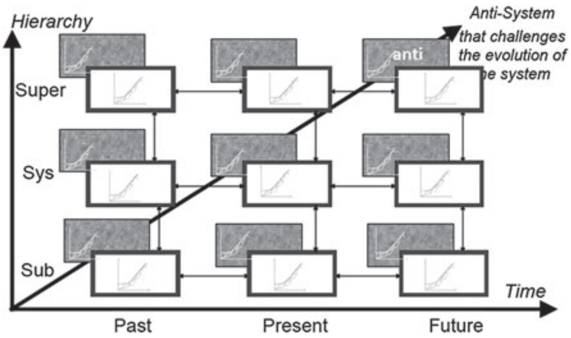

Fig. D.1 System operator or classical TRIZ multi-screen schema of powerful thinking [12]

Disregarding its original formulation, several applications of the System Operator for the scope of browsing the properties of products or processes neglect the last dimension.

For practical needs it is useful to treat each of these three dimensions as a composition of several dimensions. For instance, in practice we often face with a situation that one Element belongs to several hierarchies of systems. An airbag in the car belongs to the dashboard or the doors or the steering wheel and, at the same time, it deals with the safety of the driver and the passengers.

Depending on the specific situation we can consider Time dimension as a historical time (if we study evolution of certain systems), as a process time (while analyzing a chain of events, even with their cause-effect relationships), as a life cycle of an element of a system.

Appendix E
The Kano Model of Customer Satisfaction

The Kano model [13] is a theory to support product development, whose main hypothesis stands in the diverse contribution of product features in impacting the perceived customer satisfaction. The model attempts to overcome a classical and tacit assumption, according to which the increased level of a product performance results in a proportional growth of value for customers.

The Kano Model classifies the product attributes on the basis of their effect on customer satisfaction. It divides the relevant attributes, generally defined as Customer Requirements (CRs) in three different categories that play a different role in the product or service perception: Must-Be, One-Dimensional and Attractive.

Must-Be CRs are attributes expected by the customer, they do not provide an opportunity for product differentiation, since they are commonly accomplished also by the competitors. Increasing the performance related to these attributes provides diminishing returns; however the absence or poor performance of these attributes results in extreme customer dissatisfaction.

One-Dimensional CRs are those whose performance growth results in linear enhancements of customer satisfaction. Besides, an absent or weak performance attribute determines customer dissatisfaction.

Attractive CRs are usually not explicit and unexpected by customers but can result in high levels of customer satisfaction, while their absence does not lead to dissatisfaction. These excitement attributes often satisfy latent needs customers are currently unaware of. In a competitive marketplace where manufacturers' products provide similar performances, obtaining excitement attributes that address "unknown needs" determines a substantial competitive advantage [14].

With regards to the presented logic, whereas Must-Be and Attractive attributes pertain just the avoidance of dissatisfaction and the generation of delight, respectively, One Dimensional CRs influence both the dimensions. Eventually,

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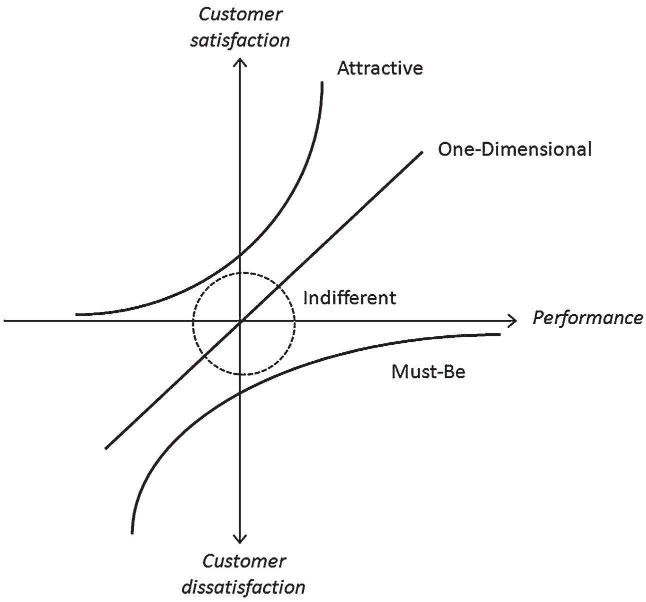

Fig. E.1 The Kano model of customer satisfaction, relating the performance of the fulfilled customer requirements and the impact on satisfaction/dissatisfaction according to the kind of product attributes

poorly relevant attributes, which can be easily disregarded are described as Indifferent attributes. The whole framework can be summarized by means of the diagram in Fig. E.1.

In order to deepen the knowledge about the employment and the development of Kano model, a recent state of the art analysis has been performed in [15].

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Business Process Reengineering driven by customer value: a support for undertaking decisions under uncertainty conditions

Abstract
The field of Business Process reengineering (BPR) has recently observed the birth of Decision Support Systems (DSSs) as a solution for overcoming the limitations of previous initiatives. The numerous flops recognized in earlier BPR implementations are mostly ascribed to the introduction of best practices from other industrial experiences without proper adaptation to the local specificities, as well as by the inadequate consideration of uncertainty issues within decision making. A considerable amount of DSSs integrates issues dealing with customer opinions and behaviours and takes into account the uncertainties related to the relevance and the implications of the gathered feedbacks. In such a context, the paper describes an algorithmic model (implemented in a computer application) for supporting decision making that quantitatively relates the phases of a business process with its outputs, with reference to the contribution in generating customer value. The proposed decision support method can be advantageously employed especially in those cases characterized by time pressure and impossibility of performing suitable customer surveys. The model sheds light on process value bottlenecks and provides indications about the most beneficial reengineering activities. Context uncertainties are managed by applying Monte Carlo simulation. Such measure allows evaluating the share of risk ensuing from redesigning certain business process phases.

Keywords
Decision Support Systems; Business Process Reengineering; Process Value Analysis; Monte Carlo simulation; customer perceived satisfaction

1. Introduction

In rapid changing and highly competitive marketplaces, industries face the challenge of continuously improving their offer in terms of products and services. The demand for innovation rebounds on the industrial environment and affects the business processes, which require continuous and controlled updates. On the one hand, companies are asked to enhance the quality of products and services, so as to fulfil the growing expectations of customers and stakeholders. On the other hand, firms strive to curb costs and, generally speaking, any other channelled resource. In this sense, a paramount importance is attributed to all those initiatives aimed at strategically redesigning industrial processes in order to accomplish significantly higher performances and that fall under the name of Business Process Reengineering (BPR). The literature witnesses considerable advantages arisen by BPR initiatives and describes textbook success stories. However, plenty of contributions from different periods (e.g. [1, 2]) point out a high percentage of unsatisfactory results concerning BPR practical implementations, causing therefore diffused scepticism in the field. Recent studies provide greater understanding about the success factors and major effects of BPR initiatives, thus advancing guidelines to generate benefits for the enterprises to the greatest extent [3-6]. The reasons of unmet expectations can be related to disparate motivations. Among them, the literature recognizes the complexity and the not deterministic behaviour of business models [7], as well as the overwhelming focus on the minimization of costs [8], with the consequent disregard of workforce interests and customer preferences.
Besides, customer-oriented approaches are largely diffused within New Product Development tasks. In this context, Quality Function Deployment (QFD) plays a central role within Business Process Reengineering, with the intended purpose of linking customer needs and product design [9]. QFD is aimed at maximizing the perceived satisfaction of potential clients, on the basis of Voice of the Customer (VoC) techniques, and indicates through quantitative metrics the most favourable mix of technical performances. However, few QFD applications have been experienced to relate product

innovation directions to practical recommendations for carrying out the redesign of the business processes at the operational level.
In such a context, companies encounter difficulties to select the most beneficial innovation strategy to be undertaken and the most suitable BPR tool for its implementation. Particular problems are experienced by small enterprises with limited investments dedicated to R&D activities. SMEs would certainly benefit of reliable and easy-to-use Decision Support Systems (DSSs), capable to support the identification of the major process criticalities and the definition of valuable redesign strategies. With the purpose of overcoming such problems, the paper proposes a system for supporting decisions, whose methodological framework has been implemented in a popular numerical computing environment (MATLAB R2012b). The system individuates the main weaknesses of a business process and highlights the most effective directions for process innovation. The proposed procedure is achieved by radically upgrading and extending a methodological roadmap [10], namely Process Value Analysis (PVA), swivelling on the role played by business process phases in fulfilling customer requirements. More in particular, the basic method has been further developed to deal with uncertainties management and to assess the reliability of the outputs. The objective of the enhancements is to strengthen the approach for undertaking decisions concerning the choice of the most favourable BPR initiatives.
The manuscript is organized as follows. The next Section presents a state of the art analysis focused on systems supporting decisions about reengineering activities. Section 3 better explains the starting point for the development of the proposal and clarifies the methodological objectives to be pursued. The fourth Section presents the designed methodological framework and its computer implementation. Section 5 shows two applications of the methodology. The former is an illustrative case study treating a manufacturing process from the pharmaceutical field, carried out by a sample of 27 MS Engineering students. The purpose of this example is to show the impact of divergent opinions between process analysts with adequate scientific rigour. The latter is a real case study from the footwear industry, for which 16 individuals have analysed the whole business process of a small Italian firm within a project of national interest. The Section further discusses the emerging outcomes of the experiments. Eventually, the final considerations are drawn in Section 6, which includes the planned future activities.

2. Related art

This Section aims at elucidating how the literature treats a wide variety of topics related to industrial innovation practices. According to the authors’ understanding, process- and product-oriented approaches separately show complementary benefits with regards to several aspects. Moreover, in the complex network of existing support systems, a difficult task is represented by weighing up the efforts dedicated to improve the quality of products and to stem the costs of industrial processes. The following sections debate the above recalled aspects and outline an initial set of requirements to define an ideal DSS for process reengineering, posing the methodological objectives of the paper.

2.1 Overview of DSSs for process reengineering

2.1.1 General features of DSSs to support BPR

BPR initiatives represent complex multidisciplinary tasks, dealing with multiple sources of risk [11] and a wide range of aspects regarding different fields of expertise [12]. Furthermore, reengineering issues have to be directed towards complex business and industrial processes, which are characterized by not deterministic behaviours and require dynamic time-dependant models. As a consequence, the uncertainty regarding the model and the parameters governing the business process affects the outputs of BPR tasks, leading firms to take extremely risky decisions intuitively rather than through a systematic analysis. It follows that consistent research efforts have been

dedicated to the development of DSSs, modelling instruments and simulation techniques aimed at increasing the effectiveness of industrial processes [13] by individuating major inefficiencies [14]. On the other hand, failures of BPR initiatives can be explained by strategies oriented on redesigning just the features pertaining the internal processes [15]. With a particular insight into process rethinking, it has been argued [8] that numerous BPR applications have been focused mainly on resources savings. Such practices, with the purpose of achieving lean processes by mimicking past experiences, have frequently underestimated the relevance of the value delivered to customers [16], conversely seen as a determinant for the success of BPR initiatives [17].
The documented decision supports for process enhancement, that have considered the supply side, have been mostly aimed at aligning business strategies towards Customer Relationship Management (CRM) [18-22]. In this sense, rather than customer-oriented BPR approaches, such DSSs represent methodologies addressed at improving a particular area of the business and industrial management. Eventually, recent proposals exploiting customer feedbacks and demands to redesign the business process are restricted to specific industrial domains, such as electronic items assembling [23] and servicing [24].

2.1.2 Accounting of uncertainty issues within BPR systems
Like any decision-making activity, the redesign and planning of business processes is associated with uncertain inputs and risk. With reference to such problem, Lambert et al. [25] take into account relevant risky factors starting from the modelling phase by representing such additional information through tailored IDEF (Integrated Definition) frameworks.
Many research efforts have been carried out about DSSs dealing with the uncertainty that characterizes a business process. Min et al. [26] developed a DSS suitable for banking industry, assessing appropriate BPR tasks under multi-criteria analysis and present constraints. Williams et al. [27] deal with risk and uncertainties associated with BPR initiatives, focusing on organizational hurdles and providing guidelines for pursuing incremental or radical changes with reference to expected benefits and available investments. Wang and Lin [28] introduced genetic algorithms in order to efficiently schedule industrial processes for a make-to-order manufacturing firm. Their research and application is tailored for resource allocation decisions in an environment characterized by time pressure with regards to delivery dates. By exploiting simulation techniques, Mahdavi et al. [29] built a model meant to dynamically control the production activities of a flexible job-shop, whereas manufacturing processes are characterized by stochastic events.
Still with regards to intelligent decision making within industrial processes affected by uncertainty, Gregoriades and Sutcliffe [30] developed a decision-based system capable to evaluate the advantages of introducing and managing a new candidate business process, whose characteristics are known. The system simulates the business process, by taking into account industrial performance and human factors, and assesses opportunities and risks on the basis of the generated scenarios. Besides, the problem of working with not deterministic and uncertain models is compounded by the presence of qualitative parameters. In such a context, recent contributions introduce measurable parameters to deal with uncertainty issues within relevant aspects related to business processes, i.e. customer relationship [20] and purchasing management [31].
Overall, the variegated aims of these contributions either enhance specific aspects of industrial strategies, or are tailored to support specific categories of firms. In this sense, they mostly lack a general and versatile approach, capable to fit the exigencies of different industrial domains and encountered problems.

2.2 QFD as a decision support to address the development of products

2.2.1 Employment of QFD within reengineering tasks
As already mentioned in the Introduction, QFD represents the main reference for product development initiatives stimulated by customer value. The employment of quantitative variables

eases the displaying and the interpretation of the arising outcomes, thus facilitates decision making. Further on, the focus of QFD on products features in the perspective of achieving customer satisfaction has resulted in a robust link with Kano model [32], thus allowing to consider the different impacts of the relevant competing factors on the perceived value [33, 34].
QFD basic principles have been exploited also to support process redesign. In [35], a modified QFD method replaces engineering features with the factors characterizing the manufacturing process, by directly relating the latter with customer requirements. The main achievement of the system is the disclosure of potential conflicts between disparate aspects concerning the business process, rather than practical hints to support decisions about the reengineering activities to be undertaken. Ultimately, besides claiming to support a wide range of reengineering activities, the positive influence of QFD on the improvement of industrial processes is questionable [36]. Its function within BPR predominantly consists in supporting the strategic positioning in the market by analysing and assessing the product performances [37] and choosing the most appropriate manufacturing means for the designed artefacts [38].

2.2.2 The management of uncertainties

Furthermore, a considerable drawback of QFD is represented by diffused uncertainty impacting the inputs and the outputs of the methodological framework.
QFD models are surveyed by Fung et al. [39] to analyse the reasons of uncertainty introduction, revealing how the relationships between customer requirements and engineering characteristics play a major role. Further on, their research surveys the effectiveness of linear programming models with fuzzy coefficients to correctly estimate the extent of such relationships.
The employment of fuzzy set theory represents the most diffused approach in the literature for managing the uncertainties and the dynamics of the inputs in QFD: Kahraman et al. [40] proposed a critical review of these applications. Experiences dealing with uncertainty carried out by means of fuzzy set theory regard also the Kano model [41, 42], as well as its conjoint utilization with QFD [43].
Geng et al. [44] introduce a fuzzy model for QFD, taking into account, beyond product characteristics, those requirements involved in services delivery and pertaining the manufacturing process. Jia and Bai [45] propose a fuzzy-QFD model tailored for manufacturing processes, whose main features are evaluated by four industry domain experts; the application of the tool finally depicts the effects of uncertain inputs in a modified House of Quality [46]. The surveyed contributions are however affected by the argued efficacy of fuzzy sets within the management of uncertainties for decisions undertaking [47]. Furthermore, the relentless difficulties in employing such complex mathematical models hinder a wide diffusion of such DSSs within a large amount of industrial contexts.

2.3 Approaches for choosing the most advantageous BPR activities

According to the above overview, the field of decision supports for BPR appears as an extremely populated set of tools and methodologies. In this perspective, a considerable support for the companies would be represented by systems capable of individuating the aspects of the whole business requiring the most beneficial reengineering activities.
In such a context, several decision supports aimed at addressing the most favourable directions for BPR initiatives apply just to peculiar features of the business strategy, such as the technical aspects of the process [48] or single units of the enterprise [49]. Reijers and Mansar [50] provide a framework of best practices for BPR tasks according to the focus of redesign efforts. He et al. [51] have developed a Fuzzy Analytical Hierarchy Process to support the choice among different alternatives of possible BPR initiatives. Eventually, Cho and Lee [52] develop a web-based tool for choosing the most suitable approach for Business Process Management, according to the evaluation criteria dictated by the business characteristics of the firm under investigation.

A methodological approach, namely Process Value Analysis (PVA) [10], has been developed in the perspective of individuating the business segments needing major reengineering efforts. The methodology characterizes the main phases of an industrial process by quantitatively determining their contribution to avoid dissatisfaction and to provide unexpected value for customers. It takes into account also the resources spent to fulfil the foreseen customer requirements. This allows highlighting the value bottlenecks of the business process, so as to address the reengineering priorities. An akin objective is pursued through the methodology proposed by Jammernegg and Kischka [53], that focuses nevertheless just on the enhancement of a peculiar segment of the business processes, i.e. the supply chains.
The PVA simulates the interplay between QFD and Kano model, although the phases constituting the business process, rather than engineering requirements are considered. The methodology differs also from the already cited proposal advanced by Jagdev et al. [35], because it investigates the single constituent activities and phases of a business process instead of global characteristics.

2.4 Summary of the survey and individuation of the main lacks within DSSs for BPR

Table 1 provides an assessment of the examined approaches with respect to a set of desirable characteristics for an ideal DSS, which have been gathered from the above survey. The table highlights, besides the primary scope of the different proposals, the level at which such characteristics are achieved according to the authors' opinion.
With reference to Table 1, the scenario of proposals for supporting BPR includes tools to prioritize aspects for product redesign, criteria to individuate weaknesses concerning the current process and practical instruments to carry out transformations at the operational level. Such tools result poorly linked with each other and the fulfilment of DSSs capable to guide the enterprises in the whole reengineering process still represents a severe challenge. The ideal result would be a system capable of individuating the aspects and the areas of the business process needing major changes and translating these inputs into practical suggestions to redesign the involved industrial activities. According to this objective, the initial step of a targeted research activity would be the achievement of a DSS module in charge of supervising the business process and remarking its main weaknesses, complying with the features illustrated in Table 1.
Such outcome may be accomplished by extending the existing contributions (with a specific reference to those closer to the ultimate goal) beyond the limitations highlighted in the survey. According to the authors' vision, three possible alternative paths can be followed:

- extending the purpose of BPR instruments based on customers' opinion;
- improving QFD-like tools tailored to investigate industrial processes;
- further developing the Process Value Analysis.

Kind of contribution to support decision making	Main aim	Kind of output to support the decisions (quantitative or qualitative)	Consideration of the customer sphere	Consideration of internal demands	Flexibility according to different industrial fields	Addressed section of the business process	Capability to account of uncertainty issues
Traditional BPR approaches [1, 2, 11, 12]	Restructuring industrial processes by suppressing low-valued activities	Diffusedly qualitative	Moderate	Very careful	Modest (due to standard solutions)	Whole	Limited
BPR approaches swivelled on CRM [18-22]	Aligning strategies towards CRM	Diffusedly qualitative	High	Varying	Varying	Just partially	Varying
BPR systems exploiting customer feedbacks [23, 24]	Reengineering business processes according to inputs from the customer sphere	Diffusedly qualitative	High	Limited	Very limited	Whole	Not relevant
Qualitative BPR approaches considering uncertainties [25-30]	Varying according to the single proposals	Qualitative	Moderate	Varying	Diffusedly low	Diffusedly just partially	Foreseen
Quantitative BPR approaches considering uncertainties [20, 31]	Reengineering strategic segments of a business process	Quantitative	Moderate	Foreseen	Limited	Just partially	Foreseen
QFD (+ Kano) [33-35]	Aligning product profiles to maximize the customer satisfaction	Quantitative	Very careful	Limited	Good	Diffusedly just the product redesign	Absent
Fuzzy QFD (+ Kano) [40, 43-45]	Aligning product profiles to maximize the customer satisfaction	Quantitative	Very careful	Diffusedly absent	Good, but complex to be applied (especially in small contexts)	Just the product redesign (in most cases)	Foreseen
Systems to choose the most valuable BPR tool [48-52]	Selecting which BPR methodologies can result the most advantageous	Mostly qualitative	Moderate	Careful	Diffusedly good	Mainly just a part of the business process	Diffusedly limited
Process Value Analysis [10]	Identifying the priorities for BPR according to value bottlenecks	Quantitative	Careful	Careful	Good	All the phases composing the whole business process	Absent

Table 1. Strengths and weaknesses of the existing decision supports for Business Process Reengineering

Candidate strategy	Main advantages	Hurdles to overcome
Extension of BPR tools based on customer feedbacks	• orientation towards practical measures to be undertaken (ease of linking with subsequent DSS modules)	• penalty for firms without efficient customer services
Enhancement of QFD approaches tailored to industrial processes	• developed capabilities to manage uncertainty issues	• arguable possibility to blend different methodologies • complexity of systems based on Fuzzy Sets
Further development of Process Value Analysis	• proper accounting of the resources spent by the industrial process • existence of preliminary indications about reengineering directions	• diffused employment of subjective evaluations

Table 2. Methodological opportunities to achieve the first module of a DSS meant to supervise the business process and highlight the value bottlenecks: strengths and weaknesses.

Table 2 summarizes the pros and cons envisioned for the above alternatives. In details, the first hypothesis regards the extension of the BPR tools swivelling on customer feedbacks, leading to a method capable to work in different industrial contexts. Such a method would indicate the most favourable redesign actions according also to the amount of resources requested to the firm for their pursuance. The advantage of this development strategy would stand in a quick link with the subsequent module of the DSS, since the existing BPR methods are considerably oriented to the practical measures for the transformation of the process. On the other hand, the resulting DSS would suffer from scarce usability for firms without developed client services, since the feedbacks of a restricted amount of customers would result in poorly reliable indications.

The second development strategy aims at employing the existing QFD-based approaches, with a particular reference to those tools involving also manufacturing and business processes and already capable to manage uncertainties. A consistent direction for the development strategy of QFD-oriented systems should regard a reliable computation of costs and resources in charge of the enterprise. Since the surveyed proposals quite differ in terms of the fulfilment of the expected characteristics for a future DSS, an opportunity (to be however verified) is represented by blending a set of QFD-oriented methods, attempting to combine the benefits of single contributions. Disadvantages would concern the complexity accounted to systems exploiting fuzzy sets and the lack of an appropriate strategy to manage uncertainty.

Eventually, the third alternative concerns the extension of the Process Value Analysis, whose intended purpose fits the expected objectives concerning the recalled initial module of a more articulated DSS. Moreover, an insightful analysis of the approach reveals that its outputs include preliminary indications about the most proper BPR practices to be implemented in order to beneficially follow the emerging reengineering directions. According to the above discussion, the main limitation of this methodology is represented by the disregard of uncertainty issues in view of a not negligible quantity of subjective evaluations about the process. An upgraded version of the PVA, capable to manage uncertainties, would require an intense testing campaign in order to assess its actual reliability.

Despite the above hurdles, the authors decided to follow the development strategy based on the extension of PVA. This option potentially allows obtaining a tool for intelligent decision making to be employed without necessarily resorting to costly and time-consuming customer surveys. The consequent methodological objectives to be pursued, better clarified in the following Section, stand in the upgrade of the system in terms of accounting for uncertainty issues, striving to safeguard the intuitiveness of the original PVA framework.

3. Methodological background and research objectives

In order to clarify the measures proposed in the present paper to develop a DSS with the enunciated scopes, a more detailed overview of the Process Value Analysis is hereby provided. Table 3 and Table 4 summarize its methodological roadmap, illustrating the steps for the determination of the inputs and the computation of the outputs, respectively. The following Subsection describes with greater detail the original structure of the methodology in a step by step fashion.

Step	Task	Outcomes	Procedure inputs
1	Information gathering	Process model, individuation of the attributes that characterize the business, sizing of expenditures relevant to each phase	List of phases; list of customer requirements (CRs)
2	Evaluating the reasons of satisfaction and discontentment	Characterization of the CRs according to their orientation in determining expected or exciting quality	Kano categories
3	Estimating the role played by product and service attributes	Characterization of the CRs according to their impact within the commercial offer; consequent determination of their share in terms of customer (dis)satisfaction	Relevance indexes *R; CS/CD* terms
4	Relating the internal sphere of the process with the business outputs	Estimation of the contribution provided by process phase in fulfilling the CRs	Correlation coefficients k_{ij}
5	Measuring the phases expenditures	Extent of employed resources, emerging harmful effects, auxiliary functions, costs and time necessary to carry out the process phases	Phases resource indexes

Table 3. Inputs of the PVA procedure.

Step	Task	Outcomes	Procedure outputs
6	Measuring the process outputs from customer viewpoint	Benefits delivered by each phase in terms of avoided dissatisfaction and customer contentment	*PCS* and *PCD* coefficients
7	Comparing the delivered benefits and the internal expenditures	Ratio between the terms expressing satisfaction and the phase consumed resources	*VN* and *VE* coefficients
8	Summarizing the results	Comparison of phases value, highlighting of the bottlenecks	Value Assessment Chart graph

Table 4. Outputs of the PVA procedure.

3.1 Description of the reference methodology

The first stage of the PVA procedure concerns the gathering of the information related to the business process under investigation. Customized IDEF0 models are suitable to represent the flows of information and materials along the process phases, as well as the employed technology, machinery, human skills. Complementary data are collected to map the

expenditures and the timing of each activity. The overall model facilitates the individuation of the Customer Requirements (CRs) that are intended to be delivered and of the organizational and/or manufacturing phases that compose the business process.
The next step of the methodology regards the investigation of the customer requirements that have been identified. Each of these product/service attributes are at first characterized in terms of the Kano categories contributing to deliver customer value (One-dimensional, Attractive, Must-be). Additionally, as within the applications of the House of Quality, relevance indexes are assigned to these attributes, expressed with *R*, meant as the relative importance of the customer requirements within the bundle of benefits provided by the business process. Such coefficients are expressed with natural numbers through a Likert-type scale, ranging from 1 to 5 in previous PVA applications. Both the Kano categories and the relevance indexes are established through customers' interviews or stated by business experts, whereas opinions of the clientele are unavailable or considered untrustworthy in the perspective of reengineering tasks.
The introduction of all Kano categories and importance coefficients allows to establish the extent of customer satisfaction *CS* (dissatisfaction *CD*) that is generated (prevented). Attractive and One-dimensional attributes contribute (according to their relevance *R*) to the *CS* term. Must-be and One-dimensional features contribute (still according to their relevance *R*) to the *CD* term. The following formulas clarify the way *CS* and *CD* of the *i*-th CR are calculated:

$$CSi = (a_i+o_i) / \sum R_k \qquad (1);$$

$$CDi = (m_i+o_i) / \sum R_k \qquad (2);$$

whereas o_i, a_i and m_i hold *Ri* if the customer requirement is classified as One-dimensional, Attractive or Must-be, respectively, 0 otherwise. The denominator stands for the sum of relevance indexes attributed to all the attributes.
The following phase consists in identifying, on the basis of business experts' evaluation, the correlation coefficients k_{ij} ($0 \leq k_{ij} \leq 1$) that link the phase *j* to each attribute *i* in terms of the accounted relative contribution of each process stage to fulfil the customer requirements (see Figure 1 for a better comprehension). Such parameters allow establishing a quantitative link among the process steps and the arisen benefits. It follows that each phase is assessed with respect to its role in both providing unexpected benefits perceived in the marketplace (Phase Customer Satisfaction, *PCS*) and avoiding user discontent (Phase Customer Dissatisfaction, *PCD*), according to the following mathematical expressions:

$$PCS_j = \sum_i k_{ij} \times CS_i \qquad (3);$$

$$PCD_j = \sum_i k_{ij} \times CD_i \qquad (4).$$

The extent of employed resources, emerging harmful effects, costs and time necessary to carry out the process phases (globally indicated as *RESj* for the share of the *j*-th phase) are compared with the terms expressing the customer satisfaction (*PCS* and *PCD*). Thus, the phases are estimated in terms of their capability to provide both basic quality and unexpected features, according to their consumption, throughout the terms Value for Exciting requirements (VE_j) and the Value for Needed requirements (VN_j), as follows:

$$VE_j = PCS_j / RES_j \qquad (5);$$

$$VN_j = PCD_j / RES_j \qquad (6).$$

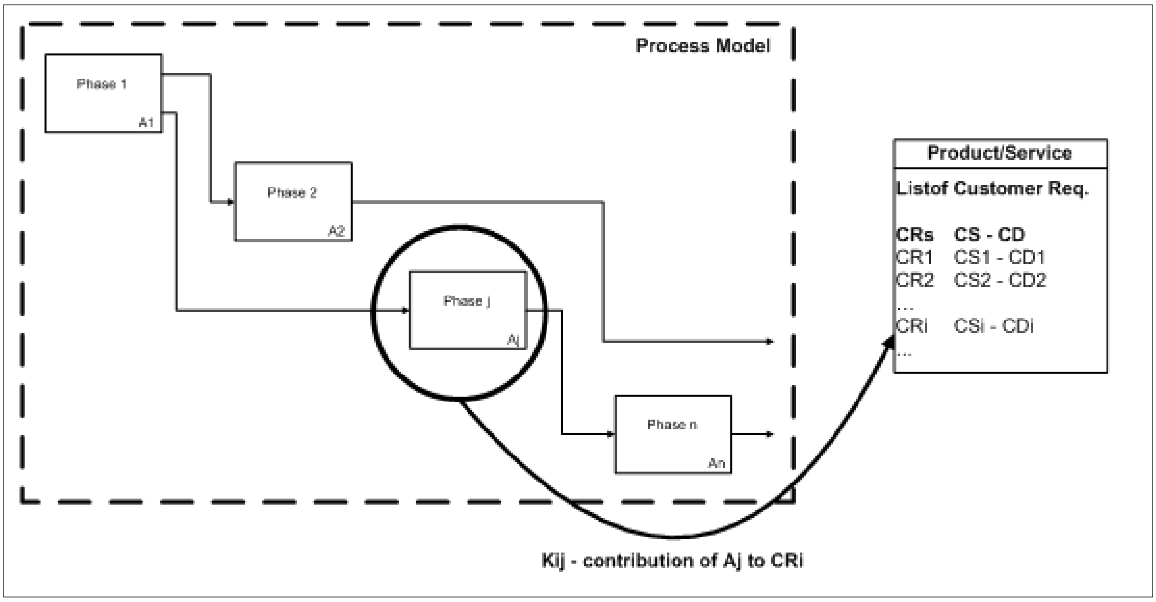

Figure 1. Meaning of the coefficients *kij*, representing the contribution of the *j-th* phase to the fulfilment of the *i-th* customer requirement [10].

The outcomes of the analysis (normalized VE_j and VN_j) are summarized in a diagram, namely Value Assessment Chart (VAC), standing in a scheme with four quadrants that represent different performance areas for process phases according to VE_j and VN_j indexes (Figure 2). More specifically, the quadrants represent:

- Area of Low Value (low VE_j and VN_j, e.g. Phases 2 and 5 in Figure 2): the employed resources do not guarantee an adequate product/service appreciation level and their extent is excessive with respect to the share of consumer dissatisfaction they are capable to avoid. As a consequence, reengineering actions should massively regard the phases falling in such quadrant: such phases are demanded to deliver novel functions and should be radically restructured in order to drop their resources consumption or even trimmed and substituted by existing process segments;
- Area of Basic Value (low VE_j and high VN_j, e.g. Phase 4 in Figure 2): the employed resources do not provide perceivable product/service unexpected benefits, but they are well spent to avoid consumer dissatisfaction; typically, the phases falling in this quadrant are oriented to fulfil the fundamental attributes and do not necessarily require investments;
- Area of Exciting Value (high VE_j and low VN_j, e.g. Phase 1 in Figure 2): in this case, the employed resources play an evident role to produce a good product/service appreciation level, but they do not contribute to avoid consumer dissatisfaction; the phases falling in this Area are worth of investments in order to maximize their generated benefits; their success is a key to let the product/service differentiate from the competitors;
- Area of High Value (high VE_j and VN_j, e.g. Phase 3 in Figure 2): this quadrant is characterized by phases capable to provide well perceivable benefits, still maintaining an extreme efficiency for fulfilling basic needs; the phases belonging to this Area are to be safeguarded.

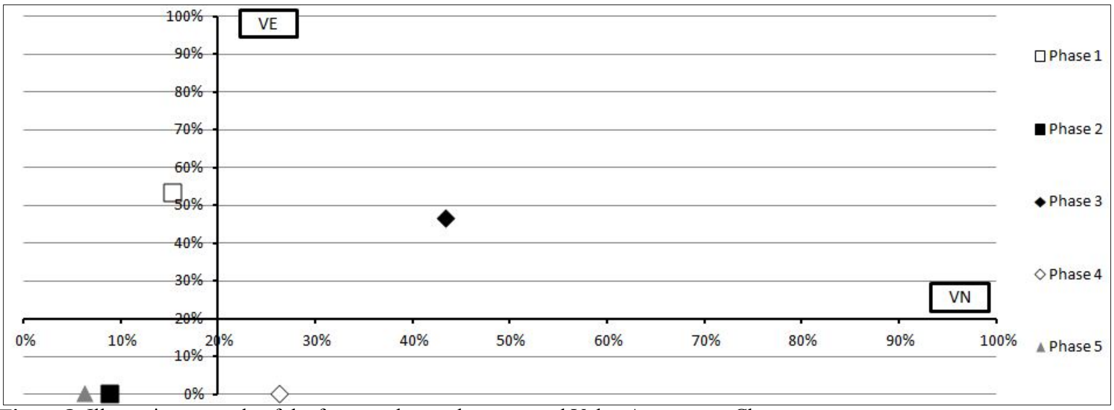

Figure 2. Illustrative example of the four-quadrant scheme named Value Assessment Chart.

3.2 Deficiencies of the original methodology
The first industrial applications of the PVA showed its capability to orientate decisions concerning BPR. However, as assessed by the developers of the methodology, consistent limitations of the methodology concern subjective evaluations about its input parameters [54]. The outputs, resulting by the algorithmic application of the procedure, are likely to suffer from imprecision and variability, which are currently not monitored.
The uncertainties may regard the classification and the relevance of customer requirements, the rates of process phases in fulfilling the aforementioned attributes, the amount of resources spent by each industrial activity when not directly measurable through monetary expenditures. Besides, the list of phases and the attributes through which the business process is schematized can differ according to single analysts.
Given the above considerations, the different estimations can be imputed to the absence of a deterministic model for the analysis of the system and by diverging evaluations of the process parameters according to experts' role (e.g. by considering the perspective of account executives and industrial production managers). Consequently, within the inputs of PVA model, epistemic uncertainty (i.e. related to the lack of knowledge or caused by measurement errors) is supposed to be more impacting than aleatoric uncertainty (i.e. provoked by the variability of the involved parameters), although the latter is not negligible.

3.3 Expected enhancements and methodological requirements
The methodological objective of the present paper is therefore to improve the decision support provided by the PVA, through the adoption of an upgraded model, capable to manage uncertainties. Table 5 summarizes the main differences between the original algorithm and the new proposal, as well as the expected achievements in the industrial practice through the consideration of uncertainty.

Feature	Original PVA	Upgraded PVA
Way of working	Post-processing of process analysis performed by a single industrial expert	Post-processing of process analyses performed by multiple subjects
Provided information	Potentially unreliable picture of process bottlenecks and strengths	Picture of the most probable process bottlenecks and strengths
Use	Determination of the most urgent BPR measures to be undertaken	Determination of the most urgent BPR measures to be undertaken; consideration of the risk associated with redesigning the structure of industrial processes

Table 5. Main differences between the new proposal and the previous reference.

As highlighted in Table 5, the new system is meant to work when multiple users analyse an industrial process by means of PVA, thus revealing the extent and the nature of divergences. Since subjectivity primarily affects the inputs of the original methodology (as already recalled in 3.2), the variability of said parameters has to be taken into account. The variability of the outputs originated from a plurality of PVA applications could be easily managed by means of descriptive statistics, but such a strategy is unsuitable in light of likely high sensitivity from the inputs. Eventually, a particular attention has to be dedicated towards employing techniques tailored to deal with the kind of uncertainty that characterizes the methodology.

4. Methodological approach for the development of an enhanced PVA

On the basis of the above discussion, the development of the PVA has to include the exploitation of data gathered from multiple sources, thus taking into account process uncertainties and estimating their impact with reference to the end results.

Since PVA follows an algorithmic logic, transforming variables initially introduced into characteristic values for the process phases, uncertainty about said inputs has to be considered in order to provide a full spectrum of possible outputs. On these premises, Monte Carlo simulation method represents an acknowledged opportunity for dealing with the uncertainty of inputs within complex mathematical models [55, 56]. Monte Carlo method is a widespread technique tailored to support decisions, due to its capability to generate scenarios according to many varying and uncertain inputs. Its employment is widely witnessed in numerous domains, including engineering [57], product development [58], business [59] and project management [60]. With a particular focus on engineering applications, the method is tailored, as assessed by Kreinovich et al. [61], to deal with both epistemic and aleatoric uncertainty.

At this stage, the objective is therefore replicating a large quantity of inputs on the basis of the data that have been introduced by a limited number of industrial experts applying the PVA on the same business process. The application of Monte Carlo method to PVA, by involving the whole range of potential values for each input (i.e. number of phases and customer requirements, Kano categories, relevance extents, correlation indexes k_{ij}, amount of resources), would result merely in a sensitivity analysis measuring the overall potential impact on the outputs, thus out of the scope of the present research. Willing to constrain the simulation with respect to specific inputs, the common approach is to replicate each input variable according to an attributed probability distribution function, which best fits previously gathered data.

In the following Subsections, an explanation is given about the choices performed to carry out the simulation.

4.1 Simulation problems

4.1.1 Problems with diverging sets of phases and customer requirements

It is expected that experts of a given business activity share a common vision about how the industrial process is organized and which outputs are offered to the customer in terms of product and service attributes. Proper modelling techniques, like IDEF0, are appraised to provide a schematic picture of the process and thus to rapidly find a consensus about the system boundaries, the phases and their outcomes.

However, discordances about the determination of the phases and the list of customer requirements could still emerge. Such mismatches determine consistent problems in the simulation task that would be better performed starting from homogeneous systems of phases and outputs valuable for the customer. In order to address such issue, the schema of an overall industrial process is favourably represented by including all the phases and requirements that have been individuated by the analysts. With reference to the missing phases or attributes of each individual analysis, the following strategy can be followed:

- all the correlation indexes and resource ratios concerning the phases that are not represented by analysts will be assigned the null value; in this way such phases do not play any role in delivering customer value, nor they impact process expenditures;
- the relevance extents of the customer requirements that are not judged impacting by analysts will assume the null value, thus providing no contribution in the determination of customer value.

4.1.2 Problems with the simulation of nominal variables (Kano categories)

Within PVA, Kano categories inputs are nominal variables, for which Monte Carlo method is not applicable. Conversely, the simulation of categorical variables is usually addressed through resampling techniques. In particular, the bootstrapping method is capable to replace sophisticated mathematical procedures thanks to the growing computational power of calculators [62] and is tailored for experiments characterized by small pilot samples [63]. The major shortcoming of such a technique stands in the impossibility to replicate nominal variables that have not been indicated by any analyst [64].

In order to overcome the problem, complex statistical tools are used that improve resampling applications otherwise biased by the absence of some, although scarcely likely, nominal values [65]. This approach does not fit however the scope of building an easily usable system. As a consequence, the authors opted to simulate *CS*/*CD* variables, which contain the information provided by Kano categories, i.e. the kind of customer perception about a specific product requirement.

4.2 Simulation choices

4.2.1 Simulating CS/CD indexes

As clarified in Section 4.1.2, it is necessary to simulate *CS*/*CD* indexes for each surveyed product attribute. *CS*/*CD* coefficients range, by definition, in the [0 1] interval and can be therefore supposed to follow a beta distribution, for which Monte Carlo simulation is applicable [66-67]. Since two shape parameters are required for the utilization of the beta probability density function, these coefficients can be calculated by exploiting the mean and the variance of the sample data (i.e. *CS*/*CD* indexes emerging from individual PVA analyses), as in [68].

The determination of the scale parameters allows therefore drawing, for each customer requirement, an array of simulations following a suitable beta distribution. The size of the array depends on the previously established number of simulations that will be indicated with *nsim* in the followings.

4.2.2 Simulating correlation indexes

The k_{ij} coefficients that express the role of the phases in fulfilling each customer requirement are positive uncertain variables with a fixed sum, i.e. 1. According to the authors' experience, the analysts of industrial processes employing PVA individuate for each product attribute one influential phase playing a major role for the fulfilment of the attribute itself. The influence of the residual phases is established with respect to the key one. By observing this characteristic behaviour, the authors have chosen a specific simulation strategy for k_{ij} variables.

A single reference phase is individuated for each product attribute, by selecting the one with the maximum average k_{ij} within the process analyses. Subsequently, for each analysis, the procedure requires to compute the ratios (indicated with k'_{ij} in the followings) between each individual k_{ij} and the values concerning the key phase. Such ratios are, by definition, positive or null variables. Their mean and variance have to be subsequently calculated. k'_{ij} ratios showing non-null variance (at least the reference phase does not own this feature) are supposed to follow a gamma distribution (being they positive or null), which allows the application of the Monte Carlo simulation method [66]. The definition of the gamma probability density function requires the knowledge of two parameters (shape and scale), that can be deducted by mean and variance also for simulation purposes, as in [69]. Hence, the varying k'_{ij} are simulated *nsim* times, while the constant ones are simply repeated in the same quantity. Subsequently, arrays of k_{ij} simulated coefficients are determined by turning the emerged proportions into shares summing to 1. For any given customer requirement and with reference to a specific simulation, such an outcome can be trivially obtained by dividing each set of ratios for its sum.

4.2.3 Simulating resources shares

As seen for k_{ij} coefficients, resource shares are uncertain variables whose sum equals to 1. If any probability distribution is established for each share, the presence of the fixed sum makes the simulation problem overconstrained. With respect to resource shares, no roundabout strategy can be applied, since analysts employ substantially different criteria to determine the impact of phases on overall process expenditures and operation times.

Such a kind of problem has been however faced in the literature, by exploiting conditional probability theory [70, 71]. By assuming a normal distribution for the treated variables, it is possible to exploit available simulation strategies suitable for implementation through specific programming languages. The authors have then partially adopted the logic and the commands suggested by an Internet resource supporting the development of scripts in MATLAB[1]. The means and the variances of the sample data are required to carry out the simulation, giving rise to *nsim*-sized arrays of resource ratios regarding each individuated process phase.

4.3 Step-by-step guided methodology and software application

This Subsection provides a step-by-step guide to perform the simulation of PVA analyses. At first, the number of the steps of the simulation has to be planned (usually some thousands), according to the expected reliability of the Monte Carlo method outcomes [72]. Subsequently, the complete list of individuated business process phases and customer requirements is collected, thus building an overall schema of the system under investigation. At first, missing data as a result of disregarded phases and product characteristics are introduced, as described in section 4.1.1. Further on, the data should be organized as follows:

1) *CS*/*CD* indexes are calculated for each listed customer requirement and each individual PVA analysis through the expressions (1, 2); their mean and variance is calculated for each customer requirement, so as to determine shape parameters for fitting a beta distribution;
2) an array of the assigned correlation indexes k_{ij} has to be built for each listed customer requirement, process phase and PVA analysis; the data are then divided for the value of k_{ij} showing the maximum mean for each customer requirement, so determining k'_{ij} indexes; means and variances of k'_{ij} variables are calculated and consequently shape and scale parameters are computed for fitting a gamma distribution;
3) an array of the attributed resource ratios has to be arranged for each listed process phase; their means and variances are subsequently calculated.

On the basis of the above inputs, the simulation is performed according to the attributed probability density functions, as described in Section 4.2. This allows to draw *nsim*-sized arrays of resource ratios, *CS*/*CD* indexes and k_{ij} shares (which are calculated after the

[1] www.mathworks.it/matlabcentral/newsreader/view_thread/304141

simulation of k'_{ij} values). The data are then used for simulating *nsim* PVA analyses, leading to the same quantity of *VE*/*VN* pairs, by means of formulas (3, 4, 5, 6). The emerging data are used to assess uncertainties about the performances of the phases in the examined industrial process. Such uncertainties can be graphically represented in a modified VAC diagram which replaces single points symbolizing phases performances with sets of the most likely *VE*/*VN* values.
The whole methodology is schematized in Figure 3, which highlights the intervals to be considered for carrying out each operation and clarifies the portion of the algorithm that can be automatically executed by exploiting the built MATLAB script, freely downloadable as an open-source web resource[2].
As highlighted in Figure 3, the mentioned MATLAB application helps to carry out the methodology especially in those parts that require greater computational efforts. The residual steps can be easily performed manually or through diffused software tools, such as spreadsheets, since they require just trivial mathematical operations (multiplications, divisions, determination of means and variances). Then, data obtained in the initial steps have to be properly introduced in the MATLAB script in order to correctly run the simulation, as specified in the description of the routine at the indicated webpage. The software application includes a main part, devoted to carry out the simulation and to compute phases performances, and a conclusive block to extrapolate the VAC diagram.
Such a module displays process performances through actual simulated data, creating for each phase a broken line that delimitates the most populated area of the graph in terms of *VE*/*VN* values.

5. Description of the experiments and discussion of the results

The performed tests have been designed to check the applicability of the methodology and of the software tool, as well as the reliability of the outputs.
A first experiment has involved people with poor experience in the treated industrial domain (pharmaceutics) and a well established process for which evolutions are known. The provided information was however sufficient for each experimenter to sketch a PVA analysis. The emerging results, in terms of decisions dictated by the VAC diagram and phases uncertainties, were compared with the real observed transformation of the investigated process.
A second experiment was then conducted by people with greater knowledge of the industry. The analysed industrial process regards the current activities of a SME producing women's shoes, involved in a research project together with the Institution of the authors. The sample of testers included some member of the management of the shoe factory and volunteer students with a good level of knowledge about the analysed industry and firm's practices. The outcomes of the application of the proposed methodology were then illustrated to the factory's direction in order to elaborate more conscious decisions about process reengineering.
Ultimately, the two tests are supposed to provide complementary results. Whereas the former is aimed at checking the applicability of the methodology and the reliability of the outputs, the latter can be exploited to evaluate its capability to support decisions in industrial environments. The tests are widely described in the following Subsections.

2 http://www.mathworks.com/matlabcentral/fileexchange/44594-pva-simulation-with-monte-carlo

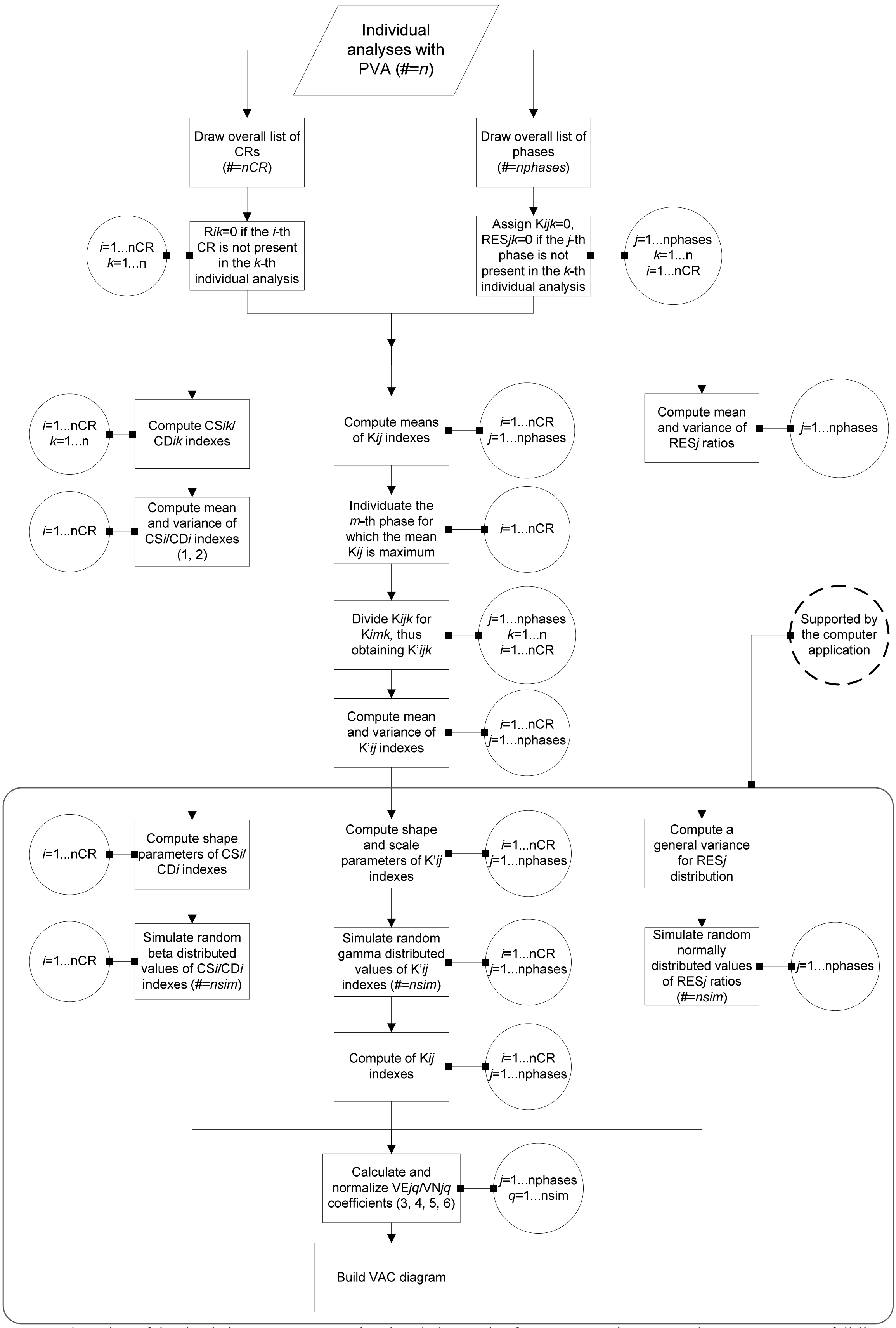

Figure 3. Overview of the simulation process concerning the whole sample of customer requirements and process segments; full-line circles indicate the interval in which to repeat the connected methodological steps; the grey-line big quadrant individuates the part of the algorithm supported by the developed MATLAB scripts.

5.1 Pilot experiment

The section illustrates an experiment, about the application of the original PVA, carried out by a sample of convenience constituted by 27 volunteer MS Engineering students, attending the course "Methods and Tools for Systematic Innovation" at Politecnico di Milano (Italy). Such a test was aimed at verifying the capabilities of the proposed approach in supporting decision tasks within BPR. The students performed the testing activity by compiling a tailored spreadsheet. The last included the options for listing the process phases, the relevant customer requirements, indicating Kano categories and features relevance, mapping all the kinds of spent resources. The system automatically computes the main outcomes and graphically displays the outputs of the methodology throughout the original VAC diagram.

The case study, extracted from a real industrial project, regards a well-established process for treating pharmaceutical powders in order to enhance the manufacturability of tablets, i.e. high-speed granulation. More in detail, the objective of the analysed process stands in the transformation of Active Pharmaceutical Ingredients (APIs) and excipients, commonly delivered in a powder state, into grains showing a good level of flowability to be easily compressed for the manufacturing of tablets. The technique consists in a prior mixing of water, API and excipient powders in order to obtain a doughy compound. The subsequent phase is represented by the chipping of the dough (a sort of extrusion) into filaments. Such formed products are in turn dried before being submitted to a further cracking so to obtain structures with the requested size of the grains. The obtained grains are subsequently sifted to select a sufficiently homogeneous output showing the required characteristics of flowability. The involved process is characterized by consistent information about its effective evolution, obtained throughout experts involvement in the research partially described in Becattini et al. [73]. More specifically, actual process developments, and hence expected indications provided by methodology stand in:

- the reduction of channelled resources for the mixing phase;
- the removal of the phases devoted to reduce the size of the pharmaceutical material (as observed in the fluidized-bed technology) or their integration with other process phases (like it is performed with the spry-drying technology);
- the key attention paid to the drying phase or to alternative activities aimed at maintaining a well-defined extent of humidity;
- a technological change for the sifting process, with the objective of strongly reducing the employed resources.

The description of the process provided to the experimenters (built upon the fundaments of drug technology and supplementary details provided by the recalled experts) reports the available information about the granulation technology, so as to allow the schematization of the industrial system and extract the knowledge relevant for PVA tasks.

On the basis of the process description, all the 27 testers individuated the same process phases, consisting in the mixing, dough extrusion, drying, filaments chipping and sifting operations. Each student described the outputs of the technical system by means of a number of Customer Requirements ranging from 6 to 10. The whole sample of CRs, that takes into account all the individuated features mentioned in the complete analysis, includes 10 items, further on named CR1 to CR10: dosage homogeneity, density and porosity, flowability, size, relative humidity, reduced volatility and contamination, mechanical characteristics, hardness, smoothness and aesthetic properties, colour homogeneity.

The gathered data about individual PVA analyses were organized in order to obtain the inputs for running the MATLAB script, i.e. means and variances about *CS*/*CD* indexes, k'_{ij} coefficients, resource ratios. The simulation consisted in drawing 10000 *VE/VN* values and employed a different kind of VAC representation with respect to the standard, because of otherwise present overlapping lines jeopardizing the clarity of the graph. The new illustration (see Figure 4) exploits Parzen windowing [74], a widespread non-parametric probability density distribution.

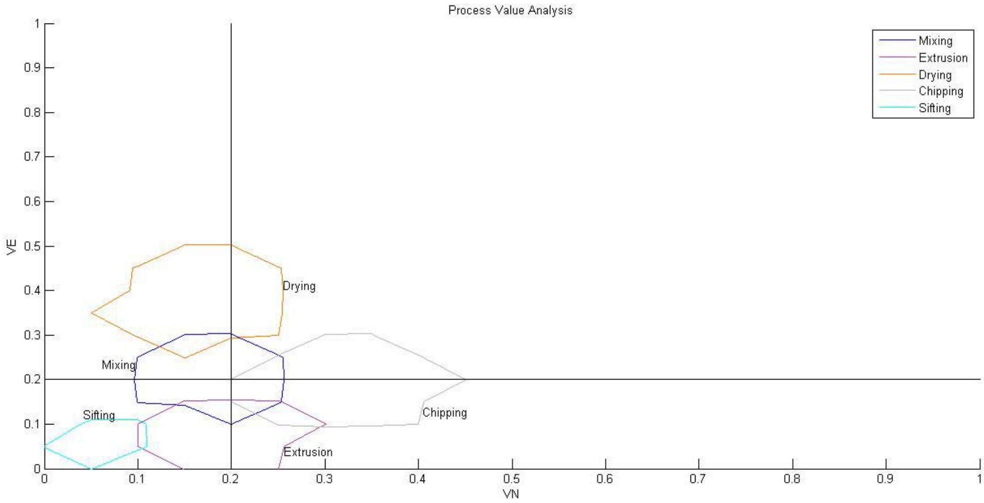

Figure 4. Representation of uncertainties through the modified VAC diagram with reference to the granulation process of pharmaceutical powders: Parzen windowing is employed for the scopes of the representation.

In order to perform such a type of representation, the final block of the MATLAB *script* was substituted by an alternative routine[3], whose drafting benefitted from an available Internet resource[4]. In details, the standard deviation of the samples was exploited for the scopes of building Parzen windows, according to the common normal distribution approximation. Parzen windowing is supposed to clearly identify the most proper areas of the VAC diagram concerning each phase for the specific case study, but, generally speaking, the literature argues that such representation can suffer from biases in the cases where some regions are denser than other [75, 76].

With respect to the present experiment, the emerging results schematized in Figure 4, show that:

- the main process value bottleneck, consisting in the sifting phase, is individuated without relevant uncertainty;
- also the dough extrusion phase is supposed to poorly contribute to customer satisfaction according to the consumed resources, since a not negligible amount of *VE*/*VN* pairs is included in the Low Value area of the VAC;
- the operations regarding the drying and the filaments chipping phases result the most value adding; while the former is particularly oriented towards the fulfilment of less expected characteristics, the latter is mostly addressed at delivering the basic properties of the granulation process;
- uncertainties about the mixing phase do not allow to suggest any suitable direction for undertaking BPR tasks.

Although affected by uncertainty, the results provide useful information for decision making. According to the general indications provided by the PVA method, the phases that represent value bottlenecks should be submitted to the most severe transformations within the technological development of the granulation process.

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[3] The script can be downloaded from the webpage:
http://www.mathworks.com/matlabcentral/fileexchange/44595-parzen-representation-of-pva-simulations
The part of the main block to be substituted is introduced by the disclaimer "% THE FOLLOWING MODULE IS AIMED AT BUILDING GRAPHICS"

[4] http://stackoverflow.com/questions/9134014/contour-plot-coloured-by-clustering-of-points-matlab

The poor value emerging by the sifting phase suggests technical changes with respect to the grain separation; as a matter of fact, less consuming pneumatic sieving are used in pharmaceutical industry, gradually replacing mechanical devices. With respect to the phase concerning the dough extrusion, also showing limited contribution to customer value, major changes should be expected. As well, the most diffused alternative wet granulation technique, i.e. fluidized bed, recur to a single phase for determining the right size of the grains, thus avoiding the preliminary volume reduction of the pharmaceutical mix. Further on, the key role played by the drying phase is remarked by the outcomes.
Besides, the urgency of lowering the required resources for the mixing phase is not identified, due to high uncertainty. In addition, the filaments chipping does not emerge as a phase that is expected to be overcome, showing conversely good performances.

5.2 Industrial application

The second experiment deals with an industrial case study from the footwear sector and shows the capability of the methodology to orientate decisions in industrial contexts. More in details, the proposed method has been applied to analyse the design and manufacturing of shoes for a factory that participates to the ongoing project "ICT4SHOES", funded by Tuscany Region, Italy. The project is aimed at introducing new ICT solutions for the production and the management of business processes in the footwear industry. The accomplishment of the task firstly requires a deep knowledge of industrial processes in order to generate tailored computer supports. The proposed methodology has been considered a reference for analysing processes and determining the main bottlenecks, hence individuating the firm activities requiring major redesign.
The firm produces women's fashion shoes, characterized by remarkable lightness and flexibility. The production is organized on seasonal basis, but, due to the factory's specialization, the shoes fit particularly hot months and, as a consequence, the success of the summer collection heavily influences the turnover of the enterprise. The style of the collections is firstly planned by experts who analyse fashion trends. The design sketches have to be subsequently transformed into physical prototypes and tested in order to check if the shoes satisfy aesthetics and comfort expectations. Once the prototypes have been refined after the test, sales start by participating to sector fairs and entrusting the commercial promotion of the items to salesmen, who operate worldwide. New customers can even purchase shoes and perform orders through a web platform. As sales progress, orders are acquired by the management of the factory and the commercial unit. On this basis, they plan the manufacturing of the orders, supervise the stock of materials (mainly the leather) and semi-finished products (such as heels, soles and accessories). The organization of the production involves also the choice of contracting firms that are in charge of developing the initial models to allow the creation of various sizes, manufacturing the dies, cutting the leather and making shoe uppers by sewing leather parts. The warehousing unit of the factory is in charge of receiving and sending to the other parties all the materials, semi-finished products and working instruments. Once shoe uppers and all the remaining components are available, the shoe factory initiates the assembling phase or supervises this activity if carried out by third parties. The manufactured shoes are then finished, checked and packaged, so as to allow the shipment of the ordered items in the requested quantity and typology.
The authors schematized a model of the business process, including phases and fulfilled customer requirements. The model was inspected and modified by the firm's management up to the determination of a framework comprising 12 process segments and 17 product attributes. Additional information was acquired in order to achieve sufficient knowledge for applying the PVA. The debate with the production manager led to a reference version of PVA for the investigated industrial process. Tables 6 and 7 sum up the analysis, whereas the former

includes the phases and the related resource ratios, while the latter illustrates the CRs together with the matching Kano categories, relevance indexes and k_{ij} coefficients.

Phase number	Phase name	Resource ratio
1	Style	0,059
2	Development of the collection	0,082
3	Testing	0,023
4	Sales	0,080
5	Organization of the production	0,082
6	Warehousing	0,107
7	Development of the models	0,045
8	Purchases	0,102
9	Leather cutting	0,082
10	Leather sewing	0,082
11	Shoes assembling	0,195
12	Completion of the orders	0,061

Table 6. Reference phases for the scheme of the business process in the footwear industry and values of the resource ratios according to the application of the PVA by the production manager of the shoe factory.

Customer requirement	**Kano category**	**Relevance**	**k-Phase 1**	**k-Phase 2**	**k-Phase 3**	**k-Phase 4**	**k-Phase 5**	**k-Phase 6**	**k-Phase 7**	**k-Phase 8**	**k-Phase 9**	**k-Phase 10**	**k-Phase 11**	**k-Phase 12**
Adaptability of the shoes to the external environmental conditions	Must-be	2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,80	0,00	0,00	0,20	0,00
Comfort	One-dimensional	4	0,00	0,25	0,25	0,00	0,00	0,00	0,15	0,25	0,00	0,00	0,10	0,00
Completeness of the shoes	Must-be	5	0,00	0,00	0,00	0,00	0,20	0,20	0,00	0,20	0,00	0,00	0,40	0,00
Compliance of the orders	Must-be	5	0,00	0,00	0,00	0,30	0,30	0,30	0,00	0,00	0,00	0,00	0,00	0,10
Manufacturing care	Must-be	4	0,00	0,00	0,00	0,00	0,00	0,00	0,16	0,16	0,16	0,16	0,16	0,20
Customer care	Attractive	2	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Extent of the collection	One-dimensional	4	0,40	0,40	0,00	0,00	0,10	0,10	0,00	0,00	0,00	0,00	0,00	0,00
Connection with the apparel trends	Attractive	3	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Limited volume of the shoes	Attractive	3	0,00	0,75	0,00	0,00	0,00	0,00	0,00	0,25	0,00	0,00	0,00	0,00
Duration of aesthetical characteristics	One-dimensional	1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,30	0,10	0,10	0,20	0,30

Allowance of variants for the ordered shoes	Attractive	5	0,00	0,05	0,00	0,15	0,35	0,35	0,05	0,05	0,00	0,00	0,00	0,00
Mechanical strength of the shoes	Must-be	2	0,00	0,25	0,10	0,00	0,00	0,00	0,00	0,10	0,00	0,30	0,25	0,00
Compliance to a brand	Attractive	1	0,80	0,20	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Possibility to reuse or recycle the shoes	Attractive	1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00
Style, aesthetics	One-dimensional	5	0,90	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,10
Variety of sizes	One-dimensional	4	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00
Option for online purchases	Attractive	2	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Table 7. Reference customer requirements for the scheme of the business process in the footwear industry and values of attributed Kano categories, relevance indexes and correlation coefficients with respect to the phases (as numbered in Table 6) according to the application of the PVA by the production manager of the shoe factory.

Overall, 13 volunteer MS Engineering students, attending the course “Product Development and Engineering Design” at University of Florence (Italy), took part of the experiment. They were introduced to the logic of the PVA, taught about the fundamentals of footwear industry and put into contact with the shoe factory in order to obtain any information they judged relevant to correctly perform the analysis of the given process. The students were urged to acquire independently further information, thus providing added value for the scope of the analysis of the industrial process. At the end of the procedure, the students and 3 other members of the enterprise’s management were asked to modify the reference framework according to their viewpoint on the market of the shoes, the process and its mechanisms that enable the accomplishment of the product attributes.

The whole sample of 16 examinations through the PVA performed by individuals with a not negligible knowledge in the field represented the starting point for carrying out the simulation. The data were then grouped and organized in order to execute the simulation with the proposed MATLAB tool[5].

Given the great quantity of phases that characterize the industrial application, it was evaluated that a separate graphical output for each process segment was preferable. The representation with broken lines was kept, but the possibility to introduce different thresholds was introduced. The strategy exploited a second alternative MATLAB block[6], substituting the final part of the main script.

[5] The data employed to perform the simulation are available in the first comment concerning the file exchange page of MATLAB, where the script is reported

[6] The script can be downloaded from the webpage:
http://www.mathworks.com/matlabcentral/fileexchange/44596-single-vac-graphs-with-threshold-selection
The part of the main block to be substituted is introduced by the disclaimer “% THE FOLLOWING MODULE IS AIMED AT BUILDING GRAPHICS”

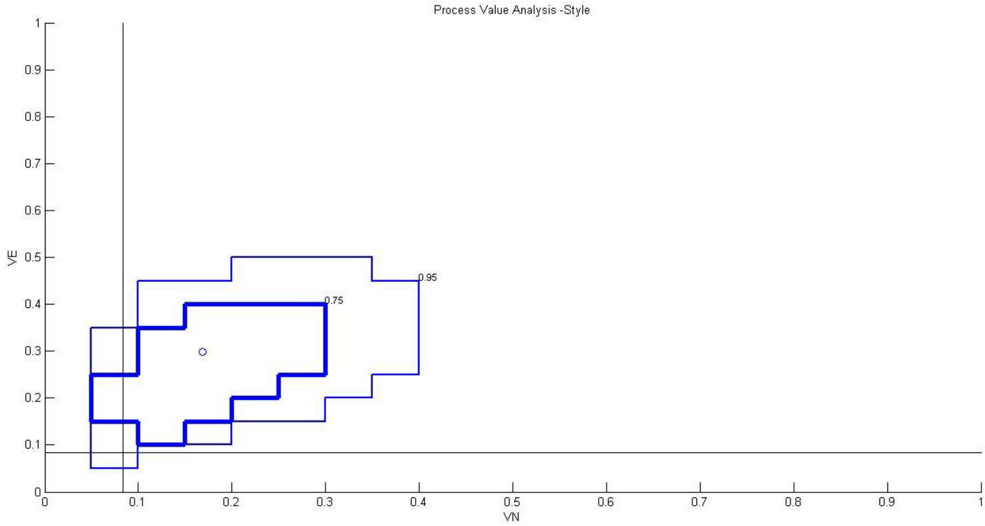


Figure 5. Representation of uncertainties referred to the phase entrusted to determine the style of shoes in the footwear industry: contours of areas comprise at least 75/95% of VE/VN simulations, as indicated in the Figure itself.

The diagram shown in Figure 5 is a result of the computerized procedure regarding the phase entrusted to determine the style of collections. Although the extent of uncertainties is considerable for this phase, the definition of the style can be considered a well performing activity, being its corresponding *VE*/*VN* pairs majorly positioned in the High Value area of the VAC. Other phases characterized by significant uncertainties face a situation for which no quadrant of the VAC is predominant and decisions can be hardly taken, e.g. testing of prototypes, which is schematized in Figure 6.

For the scope of tackling re-engineering initiatives in the shoe factory, the core of the analysis stands in the individuation of value bottlenecks. Before the application of the methodology, the enterprise had already individuated the need to update the technologies employed for warehousing activities. Figure 7, showing the diagram related to such a phase, partially confirms this choice, being *VE*/*VN* pairs concerning warehousing diffusedly placed in the Low Value area. Anyway, other quadrants are rather populated, especially Basic Value area. On the other hand, several manufacturing phases clearly represent process bottlenecks, since, although uncertainties are present, very few *VE*/*VN* pairs lie outside of the Low Value area. Figures 8 (a-c) schematize the performances of leather cutting, leather sewing and shoes assembling, respectively. It can be additionally underlined how representative areas with thresholds set at 75% and 95% of the whole simulation of *VE*/*VN* values widely overlap, especially in Figures 8 (a) and (b). Therefore, the measures of the phases performances are highly concentrated and this lessens the risks about the decisions to be undertaken.

The application of the methodology convinced the shoe factory to rethink its plans for process reengineering, considering to include also manufacturing activities within the bundle of tasks to be redesigned in order to enhance firm's performances.

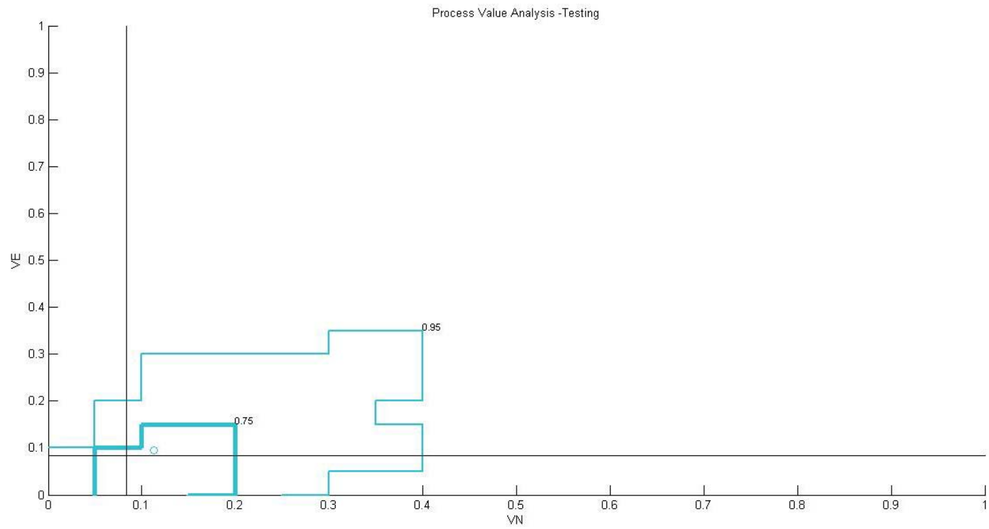


Figure 6. Representation of uncertainties referred to the phase entrusted to test prototypes in the footwear industry: contours of areas comprise at least 75/95% of VE/VN simulations, as indicated in the Figure itself.

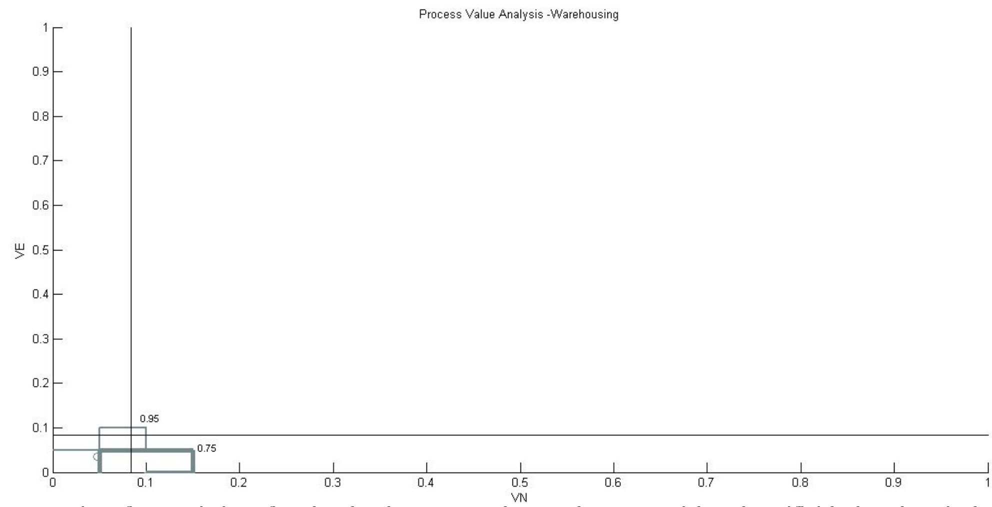
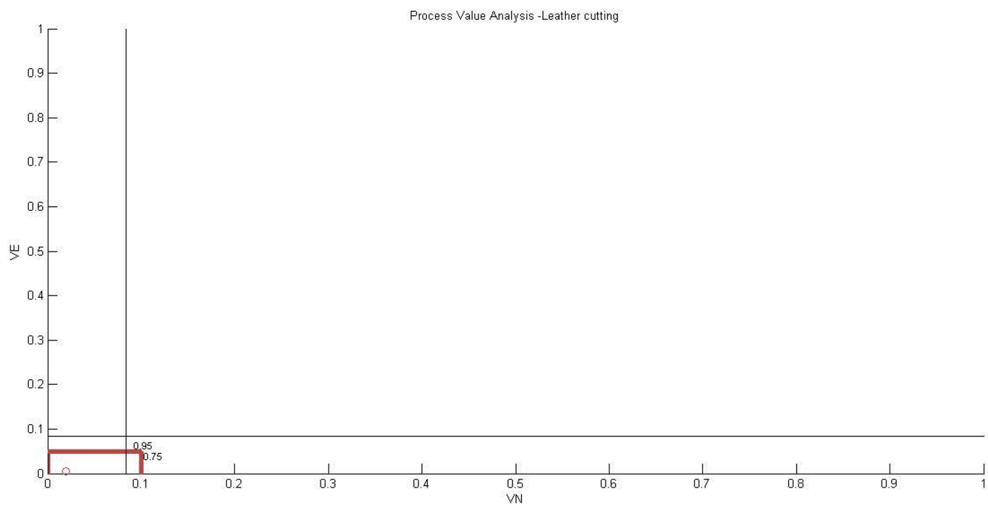
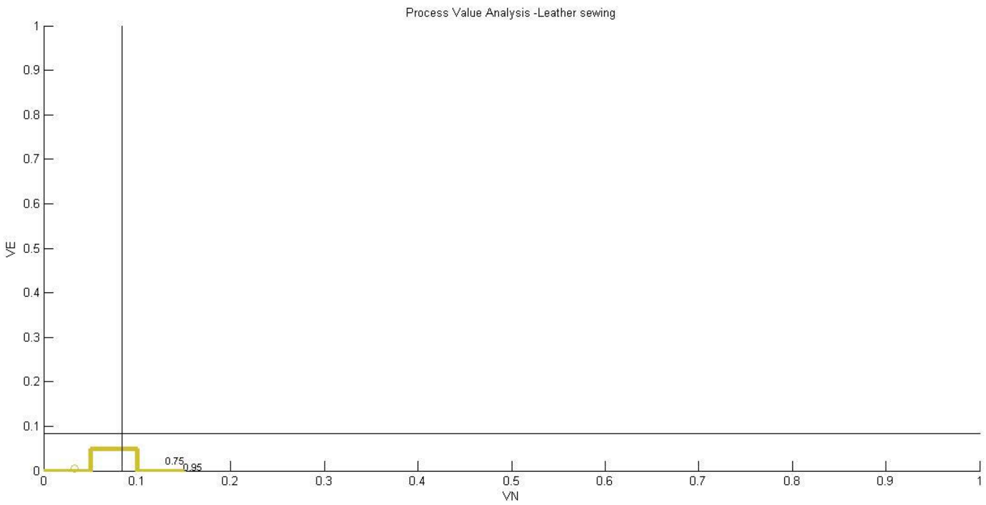


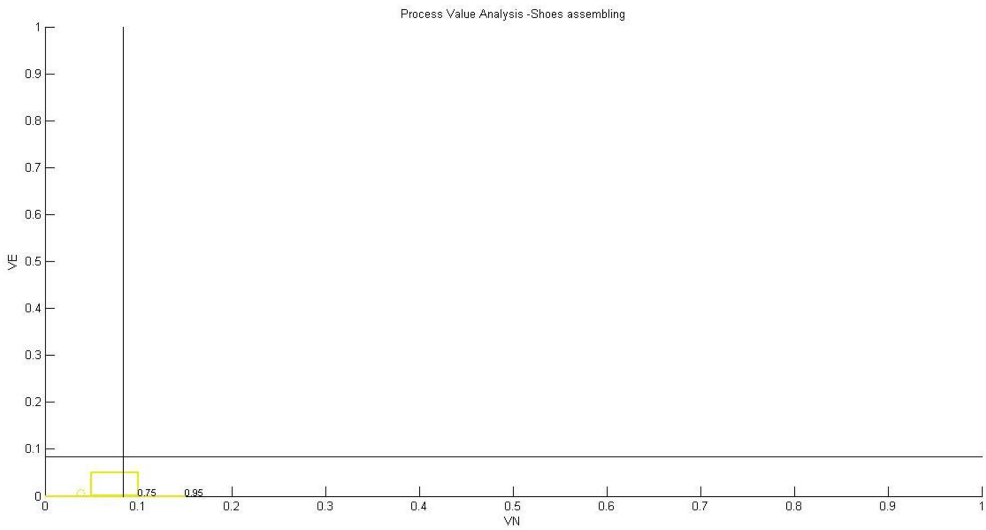
Figure 7. Representation of uncertainties referred to the phase entrusted to warehouse materials and semifinished products in the footwear industry: contours of areas comprise at least 75/95% of VE/VN simulations, as indicated in the Figure itself.



(a)



(b)



(c)

Figure 8. Representation of uncertainties referred to the manufacturing phases entrusted to cut leather (a), sew (b) leather and assemble shoes (c) in the footwear industry: the contour of areas comprise at least 75/95% of VE/VN simulations, as indicated in the representations.

6. Discussion and conclusions

Despite different methodological options should be tested (such as systems for BPR evolution, process-oriented QFD, as discussed at the end of Section 2) in order to compare the efficacy of alternative approaches, the candidate module for a DSS reported in the paper has demonstrated its capabilities with respect to the objective of the present research. Indeed, the illustrated methodology, consisting in a radical rework of the PVA [10], supports the individuation of the main deficiencies pertaining the investigated industrial process towards the goal of delineating the reengineering priorities and consequently applying the most beneficial BPR tools. With respect to the posed requirements, the module pursues the double goal of taking into account the customer sphere and evaluating the risk associated with the decisions to be undertaken, according to the level of disagreement among the decision makers.

More in detail, the illustrated system works like those DSSs that integrate information pertaining the end user domain; it uses such information to build quantitative value metrics and takes into consideration also the uncertainties concerning such issues in order to strengthen the reliability of the outputs. In the developed model, the assessment of uncertainties impact has been accomplished by integrating specific simulation tools within the original methodology. The proposed approach is suitable for supporting decision tasks in situations characterized by any of the following circumstances: superficial information concerning customer opinions; urgency of the decision such that it is not possible to collect reliable data; high variability of the context; diverging evaluations provided by sector experts. The original methodology and a novel simulation module, meant to allow the handling of diverging inputs, are characterized by the ease of being exploited by means of diffused software applications (such as spreadsheets). The task is further simplified by employing MATLAB, thanks to a script published on the web, which automate the simulation procedure and additional routines to help the building of suitable graphical representations. Consequently, such tools are suitable also for small-sized firms with limited resources and statistical competences.

The results emerging from the first verification activity highlight that the value bottlenecks of a business process can be identified in cases characterized by diverging evaluations. Although great uncertainties, low-valued process phases were individuated for both the experiments illustrated in Section 5. At the same time, the presented methodology is capable to shade light on process activities for which re-engineering could result hazardous. Anyway, improvements are expected in light of the missed identification of fruitful re-engineering activities which have taken place in the pharmaceutics industry (Section 5.1). From this viewpoint, experiments carried out only by experts should highlight the role played by the limited domain knowledge in affecting the final outcomes of the proposed tool.

More in details, the obtained results have highlighted that the proposed method:

- is capable to evaluate the impact that uncertainties have on the value indexes characterizing each phase;
- allows estimating the uncertainty of the provided outputs, hence the reliability of the consequently re-engineering actions that decision makers might undertake;
- helps the users in establishing which aspects of the business process (if any) result more fuzzy and, thus, which information elements require further investigations in order to reduce the uncertainty of the outputs.

Eventually, the whole methodology has to be further developed with the aim of suggesting suitable guidelines for BPR, also in those cases that would manifest greater uncertainty degrees with regards to process bottlenecks. From the usability viewpoint, great benefits might be obtained through expanding the part of the methodology supported by the computer application. The expected developments of the research would arouse greater interest whereas the PVA-based module would result the most efficient alternative for supporting the initial steps of a multi-stage DSS, capable to guide the users up to the choice of the technologies and practices to be implemented for favourably reengineering business and manufacturing processes.

Any interested scholar or practitioner can contact the corresponding author to receive further details about the use of the software applications, files, suggestions and information required to repeat the experiments.

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List of acronyms

API: Active Pharmaceutical Ingredient
AT: Attractive
BPR: Business Process Reengineering
CD: Customer Dissatisfaction
CR: Customer Requirement
CRM: Customer Relationship Management
CS: Customer Satisfaction
DSS: Decision Support System
IDEF: Integrated Definition
MB: Must-be
OD: One-dimensional
OS: Overall Satisfaction
OV: Overall Value
POV: Phase Overall Value
PVA: Process Value Analysis
QFD: Quality Function Deployment
VAC: Value Assessment Chart
VE: Value for Exciting requirements
VN: Value for Needed requirements
VoC: Voice of the Customer

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Investigating the Patterns of Value-Oriented Innovations in Blue Ocean Strategy™

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ABSTRACT
Several scholars dealing with business innovation individuate a great role played by customer value in achieving market success. With this perspective the investigation of prescriptive means for New Value Proposition represents a promising, although still poorly explored, domain. The paper presents an original approach to investigating past success stories focused around approaches derived from "Blue Ocean Strategy", for this new dimensions of performance and value have been introduced. The lesson learned from this survey is that certain strategies based on the fulfilment of established or overlooked customer needs provide greater market appraisal. This article introduces some preliminary directions to support the rethinking of products and services.

1. INTRODUCTION

Both business and engineering domains share a vision regarding the 21st century as an industrial era where the use of knowledge and the capability to innovate play fundamental roles in a companies' success. In the period of transition between quality-oriented and innovation-driven competition, Miles et al. [1] assess the difficulties faced by many firms due to the inadequacy of organizations and strategic mindsets in assuming knowledge as a central asset of industry. Since then, much research has been carried out to deal with continuous innovation programs. However, this has not provided results sufficient to master the competition.

More recently, Sandstrom and Bjork [2] remark how the focus has shifted from incremental product innovation to other forms of innovation, such as business model innovation. Chesbrough [3] assesses how the innovation of the business model results in a fundamental task for success, although not one easily tackled. Johnson et al. [4] point out how unsatisfactory results of many companies are due to the unawareness about the need to innovate the business model and/or reluctance in rethinking the role of the enterprise in the market.

Despite criticism about the opportunity for established companies to pursue breakthrough innovation strategies [5], the literature acknowledges the advantages gained by reinventing the business model. In this context, two issues seem to provoke the most severe limitations for systematically designing business model innovation projects.

The first issue regards the consistent lack of analysis and understanding about business models and their innovation, as claimed in Teece [6]. According to Magretta [7], the literature concerning business models innovation is rich in market triumphs that highlight successful initiatives or intuitions of industrial leaders. On the contrary, limited research has been conducted with the aim of formalizing the determinants that allow the success of business models.

The second concern is related to the different, and sometimes contradictory, meanings attributed to the term "business model" over the course of time. The divergent interpretations of the concept have consequently led to the emergence of differentiated measures to pursue innovation initiatives. However, according to Keen and Qureshi [8], a general consensus seems to have been reached, representing a business model as a hypothesis "of how to generate value in a customer-driven marketplace". Although the matter may be disputed, the concept of value proposition is definitively related to the tasks involving business model innovation. As a consequence, further insights around the dynamics followed by New Value Proposition (NVP) tasks should be viable to support enterprises that have to undertake programs related to business model innovation.

In such framework, the contribution of the present paper is an exploratory research aimed at systematically supporting NVP initiatives, thus contributing to innovative business models. The approach that has been followed is based on the investigation of successful business models that have regarded the diffusion of products and services characterized by original ways to deliver customer satisfaction. In order to explore the dynamics followed by the successful cases, the authors propose an original taxonomy. Such classification allows the comparison of standard and original product/service value profiles, i.e. the bundles of features that boost customer satisfaction; in the following paragraphs they will be indicated as "value attributes". On the basis of the outcomes of the survey, the authors have formulated a set of guidelines capable of supporting strategic choices along the value dimension of business model innovation.

The following section provides an overview of the contributions of innovation practices based on NVP. Section 3 explains the methodology used to extract the preliminary guidelines for value innovation tasks. Section 4 highlights the outcomes of the performed survey by listing the preliminary directions for innovation (namely New Value Proposition Guidelines). Section 5 provides empirical support for the validity of New Value Proposition Guidelines by examining stories of success and failure of novel business models. The paper closes with the conclusions and proposed further research issues in order to strengthen the guidelines and the process for systematizing the development of successful business models swivelling on NVP.

2. STATE OF THE ART OF BUSINESS MODELS INNOVATIONS BASED ON VALUE PROPOSITIONS

2.1 General Overview

From a historical perspective, the wide diffusion of the concept of a business model is consistent with the growing role played by Internet, and particularly by e-commerce in marketing activities. By the '1990's, the adoption of web retailing was considered as a sort of mantra for determining companies' fortunes. Despite such enthusiasm, numerous e-commerce experiences resulted in tremendous flops, as surveyed by Mahajan et al. [9], because of a lack of strategy within flawed business models [7]. As a consequence, the notion of a business model started to assume a wider meaning and to identify patterns of value creation by exploiting business opportunities [10]. On the same wavelength Chesbrough and Rosenbloom [11] individuate the primary objective of the business model in the proposition of the value necessary to provide commercial interest to technological advances. Similarly, Johnson et al. [4] depict Customer Value Proposition as the first step in the creation of an alternative business model with the aim of fulfilling unsatisfied needs.

The renewal of interest in business models is therefore associated with value innovation initiatives. Value innovation is acknowledged within studies of entrepreneurship as a fundamental strategy to obtain competitive advantage by proposing value profiles that deviate from previous industry standards. In the same context, the renewal of business models is intended as a means to achieve differentiation from competitors in ways valued by market [12]. Teece [6] focuses on the role played by value differentiation from offers of industry rivals in order to gain competitive advantage along the innovation of business models. Markides [13] argues about the nature of disruptive innovations, focusing on the features that characterize those related to business models. This type of innovations fundamentally redefines the market boundaries through new value propositions that focus on previously overlooked product or service attributes. These prove to be, valuable for the customers. In this perspective Gotzsch, et al. [14] emphasize the value provided by communicative capabilities of products, especially when the main features, e.g. performance and price, have reached their maturity.

2.2 Weaknesses of the Methods for the Delivery of Enhanced Customer Value

Consistent with customers' opinions across innovation initiatives [15], both business and design research involved with New Product Development (NPD) have witnessed a growing interest towards the generation of enhanced value and experience for end users [16]. Most of the methods developed in the consumer research field with such purpose are aimed at capturing the so called "Voice of the Customer" (VOC), whose extensive survey is presented in Van Cleef, Van Trijp and Luning [17]. Many approaches try to extrapolate the product requirements that are of major interest to the user [18]. Typically, this is done using interviewing techniques in which the customers are asked to identify the attributes they consider relevant in generating satisfaction. Other methodologies are based on observing the consumer behaviour during a "day in the life". The assumption behind these approaches is that designers can easily identify opportunities for the development of new products in response to perceived needs by examining the customer preferences. However, according to Ulwick [19], even if all these methods help in gaining knowledge of consumers and their behaviour, they cannot support the systematic identification of new product features. Indeed, asking the customers simply helps to reveal the needs they are clearly aware of, without shedding light on potentially novel valuable attributes.

From a different perspective, research has been carried to link the new value attributes to seeded and yet unrevealed needs. In this context, a theoretical background [20] has been built to relate needs theories with the emergence of new attractive customer requirements. In a similar background, studies have been performed to deepen the perception of functional and emotional features of products and services, as well as their relationships to the human needs [21]. Cagan and Vogel [22] have advanced proposals to accomplish NVP strategies based on the interplay of functional and emotional product features. However, the mentioned models result fundamentally descriptive and lack practical indications for the development of products and businesses capable to supply an enhanced customer value.

Within NVP approaches, a branch of business literature (e.g. [23]) acknowledges the benefits delivered by Blue Ocean Strategy (BOS), fine-tuned by Kim and Mauborgne [24]. Its developers combine several of the most acknowledged, and previously underlined, concepts within the field of business model innovation: proposition of unprecedented value, redefinition of market boundaries, transition from current industrial standards, etc.

2.2.1 A Focus on Blue Ocean Strategy

With reference to business innovation pivoted on value, the tools that are introduced within the BOS include the strategy canvas, graphically depicted through the value curve, and the Four Actions Framework, schematized through the Eliminate Reduce Raise Create (ERRC) Grid. The strategy canvas consists of ideas for developing a novel business model (strategic "move" in BOS jargon). The value curves stand for the graphical representation of the relative performances of products or services across the relevant factors of competition. A new curve is built by proper modifications of the current product/service attribute performances and by the introduction of previously ignored properties, throughout the employment of the Four Actions Framework.

Despite the proposed techniques, BOS currently lacks the systematic paths to envisage innovative products and services. It is claimed that the introduced tools are elegant to describe past successes, but they are not really prescriptive [25,26]. They simply provide vague indications about where to look for new market opportunities.

From the applicability viewpoint, it is relatively simple to investigate the current relevant product features to be properly removed, worsened or enhanced, by benchmarking the competition. Nevertheless, the proposition of new valuable product attributes represents a severe challenge [27]. Indeed, it has been argued that the strategy offers just useful visual tools to represent the ideas for exploiting business opportunities, while it misses proper guidelines in order to select successful value propositions among multiple alternatives [28]. As a consequence, assessing a strategy canvas results in a difficult matter [29,30]. Several scholars [31–33] have attempted to improve the robustness of the process of building the strategy canvas, taking into account the extent of importance levels attributed to competition factors in terms of customer perceived value. However, these measures can be adopted just after the relevant business features have been identified and defined. When the range of possible choices has already been consistently reduced, the actions to be applied just have to be prioritized.

A relevant matter consists in the proper actions to be applied to the various product attributes. From Kim and Mauborgne's description of Four Actions Framework it emerges that the attributes to be investigated are those related to buyer's perceived value:

- The Eliminate action concerns factors the pertinent industry has long competed on and that do not represent anymore a source of competitive advantage in terms of customer value;
- The Reduce action is related to product/service attributes that are overdesigned and that could be provided at much lower performance without affecting perceived value;
- The Raise action consists in increasing the performance of certain attributes well above the current industry standard, breaking the compromise with other features of the value curve;
- The Create action aims at introducing brand new sources of value for customers.

Thus, the company's strategy should be reoriented on those features that directly affect the buyer's perception, whereas a performance increase for a certain attribute represents a growth in customer value. However, Ziesak [33] has highlighted how Kim and Mauborgne themselves use price in their value curves and how a high score of this attribute results in a low satisfaction for customers. Thus the employment of attributes generating dissatisfaction may be misleading. The non-prescriptive formulation of the rules has resulted in several applications performed by BOS practitioners that show an incorrect use of the Four Actions Framework. These include the use of features that are not valued by customers [34,35] and mainly inherent to internal business processes [36], as well as attributes that have a reverse impact on buyers' perception and satisfaction [31,37].

Furthermore, the application of the tools is not sufficient to guard against business failure. Such issue can be counterchecked through the application of \instruments that value proposition failures. Consider as an example Motorola Iridium, whose business disaster is chosen as a reference by the same BOS authors [38]. Many authors have pointed out strategic and managerial mistakes with reference to this case study [39–42]. Nevertheless, all the previously mentioned contributions share a common vision about the customer perception of the business model introduced with Motorola Iridium. Such consensus about the user perception allows analysis of the NVP initiative concerning Iridium through a BOS lense. The investigation insights reveal that the performed value transition could be stimulated by the following actions and matching value attributes with respect to common cellular telephones:

- Create: possibility to talk wherever (geographically) in the world;
- Raise: reliability in preserving the communication;
- Reduce: lightness, practice of use;
- Eliminate: cheapness, possibility of indoors use.

As a result of the conducted review and analysis, the presented NVP approaches cannot prevent business failures. The achievement of a systematic strategy to support NVP tasks cannot therefore disregard a more careful appraisal of the dynamics followed by successful marketed items and wrong business ideas. Ultimately, the individuation of the proper user factors to be considered in order to provide greater value remains an open issue [43].

2.3 Objectives of the Research

The aim of the paper is to to systematize the individuation and the classification of the attributes subjected to modifications within successful NVP initiatives. In other words, the problem to be faced is how to correctly carry out the transformation of the product profile, see Figure 1.

The guidelines emerging from the present research originate from the analysis of the features that are switched in a large sample of successful NVP examples.

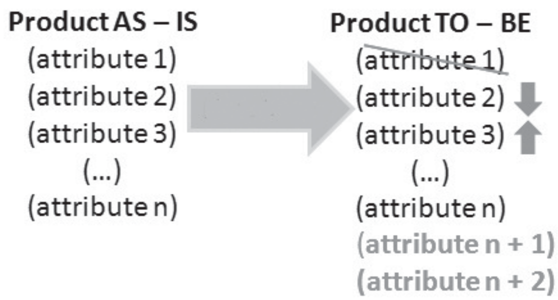

Figure 1. Problem Statement: How to Appropriately Define a New Value Profile for a Product or Service.

3. METHODOLOGICAL APPROACH OF THE RESEARCH

3.1 Investigating Guidelines Aimed at Systematizing a New Value Proposition

The author's assumption is that robust directions for the definition of value profiles for products and services emerge as a result of the investigation of acknowledged successes in the market. The analysis of winning market innovations is aimed at verifying the existence of any regularity in the reconfiguration of the product attributes. The research encompasses various phases, starting from the individuation of a meaningful sample of case studies for the investigation, to a statistical analysis about the typology of the features related to the product/service attributes whose modifications have led to NVPs. The following subsections will describe more in detail these steps, summarized in Table 1.

Table 1. Steps followed to extrapolate the guidelines

Step	Objective	Task	Tools	Outputs
1	To create a set of case studies to be investigated in order to extrapolate further guidelines	Individuating and selecting the case studies	Scientific and technical literature	A set of case studies acknowledged in the literature as successful New Value Proposition applications
2	To identify and characterize the shifts occurred to the value curves of successful products or services with respect to well-established standards	Comparing the value curves and classifying the actions applied to the attributes according to the Four Action Framework	Strategy canvas, value curve, Four Action Framework	Classification scheme of the product attributes in terms of the Eliminate Reduce Raise Create (ERRC) actions
3	To provide an insight about the retrieved attributes in terms of considering the elements that enable customer value at a functional level	Classifying the attributes in terms of functional features	TRIZ functional analysis and Ideality-based classification of the product attributes	Classification scheme of the attributes in terms of the Functional Features of the system
4	To characterize the evolution of product profiles by the modifications of the customer perceived value	Checking if the distribution is due to chance and subsequently correlating the Four Actions and the functional features	χ^2 test Statistical analysis	New Value Proposition Guidelines to perform an enriched value proposition strategy, based on Four Action Framework and TRIZ Ideality terms

3.1.1 Individuating and Selecting the Case Studies

The aim of this step is to select a representative group of acknowledged products or services that, as documented by literature, have gained uncontested success in the marketplace due to breakthroughs in the value profiles. Such examples have to be characterized by a clear set of features that undertake remarkable modifications with respect to the previous industrial standards and thus identifiable as successful implementations of a NVP strategy. In other terms, these cases can be considered neither as incremental enhancement for certain product/service aspects, nor as simple rearrangements of conflicting parameters within the industry paradigms.

The case studies described by Kim and Mauborgne in the publications that have led to the formulation of the BOS [24,44,45], have been chosen as reference samples. The wide collection of success stories employed by BOS authors to formulate their strategy is diffusely characterized by business innovations exploiting the opportunities related to previously ignored competing factors, rather than as technological breakthroughs or scientific discoveries. On such basis, the authors reckon such set as a meaningful sample for observing the phenomena that characterize business model innovations.

The described market triumphs have been further investigated through scientific and technical literature, thus obtaining additional information about the transformations occurred within the introduction of the novel value profiles. The collection of analyzed case studies is then reported in Table 2, whereas the employed additional sources are indicated.

3.1.2 Comparing the Value Curves and Classifying the Actions Applied to the Attributes according to the ERCC Model

The transformations, occurred for each case study from the traditional to the novel value curves, are substantiated by the attributes subjected by the actions foreseen within the ERRC framework. The task of this step consists of: the individuation of product/service attributes that have been introduced for the first time; elimination of the set of competing factors, subjected to a drastic change of their performance level either towards a considerable improvement or to a significant diminishment. Such attributes

Table 2. List of Surveyed Success Stories, Proposed by Blue Ocean Strategy Literature

Success story	Field	Literary sources (other than Kim & Mauborgne's)
Barnes & Nobles booksellers	Retail	[46]
Bert Claeys Kinepolis	Entertainment	[47]
Bloomberg	Finance	[48]
Body Shop cosmetics	Retail	[49-52]
Bratton's New York Traffic Police	Public Administration	[53-55]
Callaway Golf "Big Bertha"	Sport	[56, 57]
Canon copiers	Office products	[58]
Cirque du Soleil	Entertainment	[59-62]
CNN	Information	[63-66]
Compaq in server industry (1992-1994)	ICT	[67]
Curves fitness company	Wellness and beauty	[68,69]
Direct Line	Insurance	[70-72]
EFS Corporate Foreign Exchange	Finance	
Ford Model T	Automotive	[73]
Formule 1 hotels	Tourism	[74-76]
Home Depot	Retail	[77,78]
Intuit Quicken ™	Finance	[79]
iTunes	Entertainment	[80]
JCDecaux	Advertising	[81]
Joint Strike Fighter F-35	Aircraft	[82-85]
NetJets	Aircraft	[86]
Novo Nordisk Novopen®	Healthcare	[87,88]
Pfizer Viagra	Healthcare	[89,90]
Philips Alto Bulbe	Electronics	[91,92]
Polo Ralph Lauren	Apparel	[93-95]
QB House barbershops	Wellness and beauty	[96]
SAP R/2	ICT	[97-100]
Sony Walkman	Entertainment	[101,102]
Southwest Airlines	Aircraft	[103-106]
Swatch	Personal objects	[107,108]
Virgin Atlantic	Aircraft	[109-112]
Yellow Tail wines	Foodstuffs and drinks	[113-116]

involve therefore severe modifications, which can be respectively classified according to the Create, Eliminate, Raise and Reduce actions.

In some cases, the literature about the BOS already individuates and explains the actions applied to the various product/service features. However, when classifying the attributes, the recalled reverse effect of some features in terms of customer value has been taken in consideration. The authors have defined all the attributes in terms of desired outputs, whose increase implies a growth in the customer perceived satisfaction. This leads to misleading identifications of the applied actions. At the same time, particular attention has been paid to the listing of attributes without mutual interrelations and dependences, as well as communalities in the contribution to more general valuable aspects for the customers. Thus, the sets of competing factors include just decoupled evaluation parameters that play an independent role in the generation of customer perceived value.

3.1.3 Classifying the Attributes in terms of the Functional Features

The survey about the actions applied to value attributes within BOS cases, performed at the previous step, is viable as an overview of the relative diffusion of the general measures applied to the bundle of product features in the definition of the resulting value profile. In the authors' vision, such information would not be enough to support the product development cycle from the perspective of successfully redefining the value profile. In order to better characterize the common patterns followed by successful transitions, an in-depth analysis of the attributes subjected to the recalled actions has to be performed.

This analysis should employ taxonomies suitable to identify distinguishable triggers in the generation of customer perceived value.

From this point of view, no universal classification of the attributes is documented, neither within business field, nor regarding product planning tasks. The authors propose the implementation of a taxonomy based on categories belonging to the TRIZ body of knowledge [117]. The choice is motivated by its richness of instruments and techniques addressed to provide comprehensive and multifaceted descriptions of products, problems, functions, interactions between systems and their features.

The employment of TRIZ heuristics in business tasks is relatively limited, although growing. Currently, the most diffused approach, despite being in the embryonic stage, is to introduce TRIZ categories in order to support the individuation of attributes or features viable to be taken into consideration for value transitions [118,119].From the viewpoint of attributes clustering, the employed classes, with a particular reference to the 39 parameters of the Altshuller's matrix, are mostly related to the assessment of technical systems and do not cover the whole domain of product/service values perceived by the customer. According to the authors' vision, more general classification criteria could be drawn from the ideality concept of TRIZ [117]. In order to adopt a taxonomy, the focus of the investigation has to be moved from technical systems to their impact on humans perception.

Due to this choice, the guidelines that the paper aims to extrapolate are based on the classification of the attributes into three main categories (functional features), representing the terms that characterize the Ideality according to TRIZ. By considering the viewpoint of the end user of the system under investigation, the methodological purpose of this step is to distinguish the attributes, among:

- **UF** - Outcomes of the useful functions;
- **HF**- Measures to attenuate or avoid the inconvenience due to undesired/harmful side effects;
- **RES** - Efforts aimed at mitigating the consumption of resources.

Due to such definition of the functional features' classes, the increase of each attribute results in a growth of customer perceived value.

The classification and subsequent categorization (through clusters that will be indicated as sub-functional features) comply with a previously proposed classification for the Evaluation Parameters of a technical system [120].

Then, the UF attributes are further distinguished into:

- **THR** - Threshold achievement the capability to impact the user at an expected extent;
- **VER** - Versatility the capability to adapt the behaviour according to different operating conditions;
- **ROB** - Robustness the capability to provide the same desired outcome under varying inputs;
- **CTRL** - Controllability the capability to modify the desired outcome according to the user's will.

The **HF** attributes are classified by considering the direct receiver of the undesired effect, as:

- **OBJ** - The harm impact of the Object of the main function of the system e.g. when the mechanism itself adopted to deliver a desired function at the same time causes the undesired side effect;
- **SYS** - The receiver of the undesired effect is the System under investigation itself when drawbacks or certain operative conditions jeopardize the integrity and/or reliability of its parts/phases;
- **SUP** - The external environment or some element of the Super-system that should be safeguarded are harmed, e.g. when dealing with pollution.

The **RES** attributes are subdivided in terms of the kind of resources needed by the user to make the system work properly. An additional customization of the classification has been performed with respect to [120], in order to consider also any kind of expenditure required by buyers or any stakeholder. The RES attributes are therefore distinguished in terms of the diminished consumption of:

- **SPA** – Space, e.g. the reduced critical dimensions;

- **TIME** - Time e.g. quickness in delivering certain operations or a reduced time requested for system set up and maintenance;
- **INF** - Information, know-how, need of practice and/or experience, e.g. ease of use;
- **MAT** - Material, e.g. the avoided employment of tools or substances;
- **ENE** - Energy, e.g. power efficiency;
- **COS** - monetary Costs, e.g. cheapness.

Table 3 provides an example of a classification of the attributes in terms of both functional and sub-functional features, as well as the indication of the actions to which they are subjected. The example concerns the business model developed by Netjets, which has introduced the fractioned property of private airplanes. Wealthy individuals or large companies can buy flight time rather than private jets. This results in a dramatically simpler administrative management of the travel. On the other hand, times required for urgent transportation are higher than those carried out through private jets, although the differences are generally tolerable.

Table 3. Exemplary Classification of the Attributes Subjected to the Actions in a Successful Value Transition

Case	Action	Attribute	Functional feature	Sub-functional feature
NetJets	CREATE	Time saving for aircraft administration	RES	TIME
	CREATE	Ease of aircraft management	RES	INF
	CREATE	Savings on deadhead costs	RES	COS
	RAISE	Purchase cheapness	RES	COS
	REDUCE	Travel flexibility	UF	VER
	REDUCE	Flight speed	RES	TIME

3.1.4 Correlating the Four Actions and the Functional Features

The goal of this step is to delineate the emerging guidelines by assessing the results of a statistical analysis. Once the attributes are classified according to the above-defined criteria and the proper actions are identified, their mutual correlations are counted.

The significance of the attributes classification is then evaluated by considering the differences among observed and expected features distribution and consequently evaluating, through χ^2 tests, whether the effective distribution could be due to chance.

Subsequently the observation of the outcomes and specifically of the most occurring and the rarest mutual correspondences among attributes' classes and actions, allows extrapolation of the New Value Proposition Guidelines. Such directions provide indications of the most viable measures for building successful new value curves as a support of innovative business models and regarding what to avoid at the greatest extent in order to prevent from failing propositions.

4. OUTCOMES OF THE RESEARCH

This section describes the outcomes of the survey performed about the classification of the attributes subjected to modifications within NVP successes and the emerging implications.

4.1 Overview of the Results

The analysis of the previously listed 32 case studies has led to the identification of 288 attributes involved in value transitions. The subsequent survey has been conducted just on those customer requirements that received the same classification as resulting by an analysis carried out by three research fellows. Of this 273 attributes out of 288 received an identical categorization both in terms of applied action and functional feature at the first level of classification. The characterization of 232 customer requirements out of 273 resulted undisputed also at the second level of classification.

The controversial clustered attributes have not been considered for the preliminary investigation of the guidelines. In other words, at both the functional and sub-functional level, only the attributes having convergent classification by the three research fellows have been employed as the overlay of the subsequent statistical analysis.

The overall distribution of the applied Four Actions is depicted in the last column of Table 4. It shows a wide majority of value enhancing measures (Create and Raise techniques) representing about two thirds of the total. The calculation of a confidence interval (with 95% confidence level) by means of the frequentist statistical inference highlights that the share of value-adding actions for a sample of successful case studies should range from about 60 to 71%. Such actions result as strongly predominant if compared with the number of measures that entail a drop in the customer satisfaction (Reduce and Eliminate techniques).

4.2 Statistical Evidences according to the First Level of Classification

According to the classification of the functional features, the attributes are distributed as summarized in the last row of Table 4. Such distribution shows that the majority of the attributes pertain to outcomes related to useful functions, while the number of those related to the mitigation of negative effects and resource consumption is considerably smaller. The data show therefore that the biggest attention is focused on the desired effects for the user. Table 4 depicts also the number and the related percentage distribution of the functional features along the Four Actions (white cells).

Table 4. Distribution of the Attributes According to the Actions they are Submitted and the Functional Features

	UF	HF	RES	TOTAL
CREATE	45 (60.0%)	7 (9.3%)	23 (30.7%)	75 (27.5%)
RAISE	40 (39.2%)	15 (14.7%)	47 (46.1%)	102 (37.4%)
REDUCE	41 (71.9%)	5 (8.8%)	11 (19.3%)	57 (20.9%)
ELIMINATE	31 (79.5%)	2 (5.1%)	6 (15.4%)	39 (14.3%)
TOTAL	157 (57.5%)	29 (10.6%)	87 (31.9%)	273 (100.0%)

Such data are firstly employed to perform a statistical test to assess whether evidence can be drawn from such distribution. At first, it is required to determine at which extent the distribution can be considered meaningful rather than due to chance. By employing the χ^2 test, the null hypothesis affirms that no association exists among the variables of the samples. With reference to the performed experiment, the hypothesis to be accepted or rejected is specifically the similitude of functional features distribution within the actions. In order to carry out this task, the authors have employed the software Minitab v.16. By setting the confidence level equal to 95% (with the level of significance being consequently 0,05), as common by a rule of thumb, the outputs of the software have resulted the following:

- All the samples are large enough to obtain sufficient expected counts and the p-value (i.e. the statistical likelihood of distributions due to chance) for the test is accurate;
- It is possible to assess that there are differences among the outcome percentage profiles at the 0,05 level of significance, according to a very low p-value, as better remarked in Figure 2; consequently the probability of a distribution due to chance is minimal;
- The differences among the observed and expected values for the numerousness of each functional feature (Figure 3 and Table 5), are depicted in Figure 4.

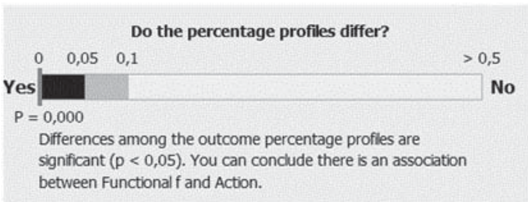

Figure 2. Assessment of the Significance of the Attributes Distribution According to the First Level of Classification.

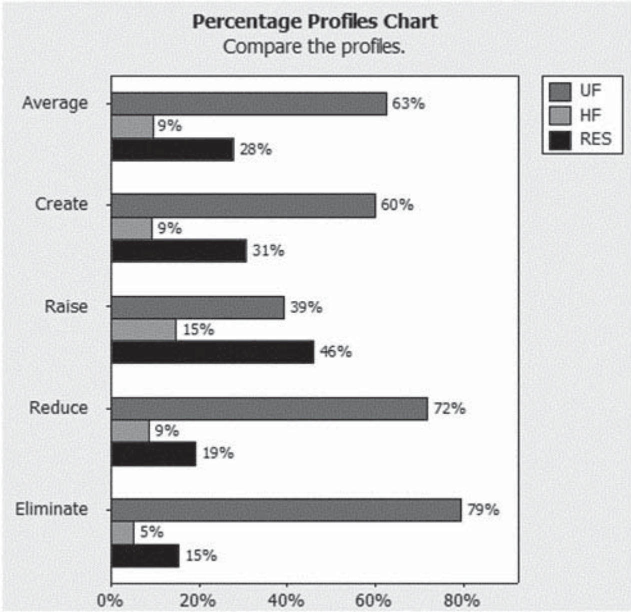

Figure 3. Observed and Expected Outputs for the Attributes According to the First Level of Classification

Table 5. Result of the Chi-Square Test for Association about Functional features by Action Diagnostic Report, as performed through Minitab

Observed and expected counts
Expected counts should be at least 1 to ensure the validity of the p-value for the test

	Create		Raise		Reduce		Eliminate	
	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp
UF	45	43	40	59	41	33	31	22
HF	7	8,0	15	11	5	6,1	2	4,1
RES	23	24	47	33	11	18	6	12
Total	75		102		57		39	

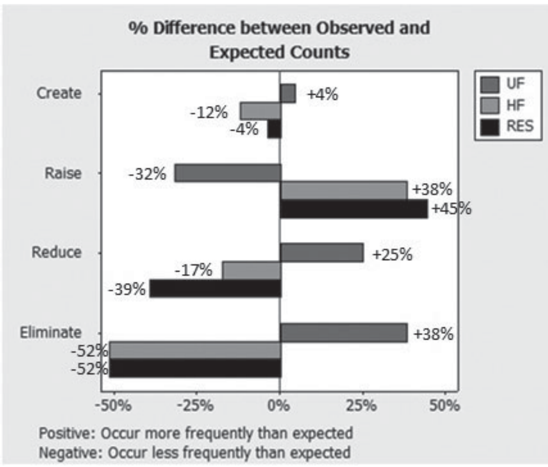

Figure 4. Differences among Observed and Expected Outputs for the Attributes according to the First Level of Classification.

The calculation of the expected output is performed according to the overall distribution of the functional features, whereas the quantity of the attributes undergoing each action is set as a constant. Figure 4 highlights the differences between the real and the forecasted occurrences (or, equivalently, their corresponding ratios as depicted in Table 4) of the functional features within each action, normalized with respect to the expected output (or percentage). The numerical values of the differences, reported in Table 4, representing meaningful indicators for the definition of the preliminary guidelines aimed at supporting the renewal of business models.

The analysis of the general distribution of the attributes (Table 4) and the percentage gaps bring the following relevant indications that constitute the main core of the statistically supported New Value Proposition Guidelines:

- No particular preference is noted in the implementation of new attributes. Hence the outcomes of Useful functions (UF) and the mitigated inconveniences due to harmful effects (HF) or resources' consumption (RES) follow a distribution within the Create action that is pretty similar to their global distribution;
- Within the raise action the meaningful mitigations of the inconveniences due to HF and to the consumption of resources (RES) seem to be recommendable; conversely enhancements, although relevant, of the performances related to attributes classified as Useful Functions, do not show likewise benefits for the end user;
- The main trend related to the Reduce action is the drop of the performances defined as UF; on the other hand, the increase of needed resources is scarcely diffused and it could be strongly inconvenient;
- The Eliminate action tends to be applied mainly to the UF attributes and seldom to the features classified as HF and RES; therefore it seems to be extremely risky to introduce harmful effects previously absent or to foresee the employment of new kinds of resources; thus, when some outcomes of the system have to be jeopardized, in order to allow a new value proposition, the preliminary observations strongly advise to address the removal of attributes consistent to useful functions.

4.3 Statistical Evidences according to the Second Level of Classification

The analysis of the attributes classified according to the second level categories defined above, was performed with reference to the same procedure described in Section 4.2. Once the general distribution of the attributes, clustered at the second level of classification, was stated as significant by means of the χ^2 test, each set of sub-functional features is separately discussed, so as to draw the conclusions for the determination of more specific New Value Proposition Guidelines.

4.3.1 Comparing the Observed and Expected Distribution of the Sub-functional Features

Table 6 reports the outcomes of the attributes analysis for the second level classification; the last row summarizes the percentages of the overall diffusion related to each sub-feature, through which the expected outputs, depicted in Table 7, have been further calculated.

Table 6. Observed Occurrences of the Sub-Functional Features along the Four Actions

	UF features				HF features			RES features					
	THR	ROB	VER	CTRL	OBJ	SYS	SUP	SPA	TIME	MAT	ENE	INF	COS	Total
CREATE	21	2	9	5	2	0	3	0	6	1	0	8	4	61
RAISE	18	5	6	4	10	2	2	3	13	0	2	8	19	92
REDUCE	18	0	7	2	3	0	2	0	4	0	0	2	5	43
ELIMINATE	13	0	12	3	0	1	1	0	1	2	0	2	1	36
TOTAL	70	7	34	14	15	3	8	3	24	3	2	20	29	232
%	30,2	3,0	14,7	6,0	6,5	1,3	3,4	1,3	10,3	1,3	0,9	8,6	12,5	100,0

Table 7. Expected occurrences of the sub-functional features along the Four Actions.

	UF features				HF features			RES features						
	THR	ROB	VER	CTRL	OBJ	SYS	SUP	SPA	TIME	MAT	ENE	INF	COS	Total
CREATE	18,4	1,8	8,9	3,7	3,9	0,8	2,1	0,8	6,3	0,8	0,5	5,3	7,6	61
RAISE	27,8	2,8	13,5	5,6	5,9	1,2	3,2	1,2	9,5	1,2	0,8	7,9	11,5	92
REDUCE	13,0	1,3	6,3	2,6	2,8	0,6	1,5	0,6	4,4	0,6	0,4	3,7	5,4	43
ELIMINATE	10,9	1,1	5,3	2,2	2,3	0,5	1,2	0,5	3,7	0,5	0,3	3,1	4,5	36
TOTAL	70	7	34	14	15	3	8	3	24	3	2	20	29	232

The availability of observed and expected occurrences allows the χ^2 test; the investigation has been carried out for the whole distribution and for each subset of attributes categories according to their matching first level of classification. Each analysis concerns the comparison between the resulting p-value, indicating the significance ratio of the test, and the established significance level (95%).

The test concerning the overall distribution had to be performed in order to assess the significance of the second level of classification within the current research. Due to the emergence of a very low p-value (0,0028), the general distribution can be considered meaningful also at the second level of classification.

The single analyses referred to each functional feature has been deemed as constraining for the discussion of the results and the consequent formulation of the guidelines. By means of the χ^2 tests, the computed extents (p-values) at which the distributions can be considered as resulting by chance are:

- 0.36% for the sub-functional features grouped within the UF attributes;
- 14.18% for the sub-functional features grouped within the HF attributes;
- 1.28% for the sub-functional features grouped within the RES attributes.

With the p-value related to the HF attributes greater than 0,05, the discussion must skip the results originated within this subset due to limited reliability. As a consequence the following subsections are aimed at providing insights about the investigation concerning the UF and RES features.

4.3.2 About the Sub-classification of UF Attributes

The percentage gaps of the second level of classification of UF attributes are summarized in Table 8. The coefficients are calculated with reference to the observed and expected occurrences reported in the Tables 6 and 7.

Table 8. Percentage Gaps between the real and expected distribution of the attributes within each action according to the UF sub-functional features: most remarkable values are highlighted.

	THR	ROB	VER	CTRL
CREATE	14%	9%	1%	36%
RAISE	-35%	80%	-55%	-28%
REDUCE	39%	-100%	11%	-23%
ELIMINATE	20%	-100%	127%	38%

The analysis of such values identifies the following relevant trends to be integrated within the New Value Proposition Guidelines:

- Emphasis is attributed to the creation of customer requirements related to the controllability of the system;
- A tendency is observed to consistently raise the capability to provide the same desired outcomes under varying inputs (robustness);
- The Reduce action is preferably addressed to diminish the value of UF attributes that are ranked into Threshold achievement;
- Features that are eliminated or that do not represent competition issues, deal significantly with the versatility and the adaptability of the system, i.e. NVP tasks can arise by focusing on certain kind of customers (specialization).

4.3.3 About the Sub-classification of RES Attributes

The percentage gaps related to RES attributes are listed in Table 9. Following the same mechanism employed for the previous attributes subset, the gaps are computed with reference to the observed and expected occurrence values reported in the Tables 6 and 7.

Table 9. Percentage gaps between the Real and Expected Distribution of the Attributes within each action according to the RES Sub-Functional Features: most Remarkable Values are Highlighted

	SPA	TIME	MAT	ENE	INF	COS
CREATE	-100%	-5%	27%	-100%	52%	-48%
RAISE	152%	37%	-100%	152%	1%	65%
REDUCE	-100%	-10%	-100%	-100%	-46%	-7%
ELIMINATE	-100%	-73%	330%	-100%	-36%	-78%

According to the coefficients presented in Table 9 the following preliminary indications can be outlined in order to enrich the set of New Value Proposition Guidelines:

- Benefits can arise by introducing new features centred on the reduction of employed resources in terms of required information, know how, practice of use materials. On the contrary, competing on price and on the need of energy is not advantageous at the same extent;
- Positive feedback is the result of attenuating the user needs in terms of energy and space; a leap concerning the cheapness of the system is consistently advantageous, thus substantially confirming one of the main assumptions of the BOS, claiming benefits by pursuing both differentiation and low cost;
- The increase of each kind of resources demands for the customer has to be avoided; however, time requirements and direct costs, on which competition is already based, is the least impactful
- The introduction of novel resources demands, if necessary, should be based on materials; analogous measures related to other kinds of resources have to be consistently discouraged.

5. EMPIRICAL EVIDENCE OF NEW VALUE PROPOSITION GUIDELINES

5.1 Evidences from Acknowledged Success and Failure Stories

At the current stage of the research, the main benefits of the arisen guidelines stand in a set of recommendations which appears as capable to support the ideation of successful new value profiles. Such claim has to be verified in terms of potentially avoiding failing NVP initiatives and complying with acknowledged successes. Both situations are tested taking into account acknowledged cases from the business literature.

Section 2.3 has introduced the case of Motorola Iridium as a reference market flop. By analyzing and classifying the recalled attributes subjected to the Four Actions, the value transition could be schematized as in Table 10, which includes the pertaining percentage gaps arisen by the above survey.

Table 10. Value Transition Followed by Motorola Iridium

Case	Action	Attribute	Functional feature	Observed percentage gap	Sub-functional feature	Observed percentage gap
Motorola Iridium	CREATE	Possibility to talk wherever (geographically) in the world	UF	+4%	VER	+1%
	RAISE	Reliability in preserving the communication	UF	-32%	ROB	+80%
	REDUCE	Lightness	RES	-39%	ENE	-100%
	REDUCE	Practice of use	RES	-39%	INF	-46%
	ELIMINATE	Cheapness	RES	-52%	COS	-78%
	ELIMINATE	Possibility of indoors use	UF	+38%	VER	+127%

Beyond the greater value reducing actions as compared with the measures undertaken to increase customer satisfaction, the transition infringes several guidelines. The proposed value profile stresses the functionality of the product to the detriment of the committed resources from the end user's perspective. Although the measures attained for the UF attributes result suitable for a successful value proposition, the higher resources demands involve sub-functional features showing severe drawbacks.

Kim and Mauborgne themselves [121], in a paper discussing a posteriori the authoritativeness of their strategy, mention Nintendo Wii as a textbook success story. Several innovation scholars [33,122,123,124], acknowledge such video game consoles as one of the most brilliant value propositions. The authors analysed the value transition followed by the successful home videogame console, employing the mentioned sources and the information gathered from domain specific web pages. The outcomes of the survey regarding Nintendo Wii are reported in Table 11, which comprises the percentage gaps arisen in the above survey.

Table 11. Value transition followed by Nintendo Wii

Case	Action	Attribute	Functional feature	Observed percentage gap	Sub-functional feature	Observed percentage gap
Nintendo Wii	CREATE	Integrated wireless joypad	UF	+4%	THR	+14%
	CREATE	Suitability of the videogames for both genders and any age	UF	+4%	VER	+1%
	CREATE	Player customization and identification (through Avatar creation)	UF	+4%	THR	+14%
	CREATE	Integration with everyday life	UF	+4%	THR	+14%
	RAISE	Sport & Fitness options	UF	-32%	THR	-35%
	RAISE	Usability of the joypad	RES	+45%	INF	+1%
	RAISE	Interactive extra features	UF	-32%	THR	-35%
	RAISE	Ease of placement near TV screen	RES	+45%	INF	+1%
	REDUCE	Appealing game titles	UF	+25%	THR	+39%
	REDUCE	Graphics	UF	+25%	THR	+39%
	ELIMINATE	HD support	UF	+38%	THR	+20%
	ELIMINATE	DVD player	UF	+38%	THR	+20%

At first, it is worth note that the actions involving a growth of the customer value constitute the two thirds of the whole set. The measures aimed at reducing the system benefits concern uniquely UF features, specifically clustered as THR at the second level of attributes classification: for both the "Reduce" and "Eliminate" actions, such direction is compliant with the New Value Proposition Guidelines. In agreement with the findings of the current research, the resources demands, specifically in terms of practice of use (RES/INF) for the reference case study, are substantially diminished.

6. CONCLUSIONS AND FUTURE DEVELOPMENTS OF THE RESEARCH

The survey represents a contribution to the understanding of the dynamics of successful value propositions viable to support the introduction of product and services characterized by an innovative profile of values. The assumption behind this study is that attribute variations charactering successful NVP transitions present regularities beyond their market sector. In this perspective, the mentioned successes can be mapped, allowing a statistical analysis and extract operative guidelines for the definition of thriving value profiles.

In such perspective, the survey of a sample of NVP cases (thirty-two success stories at the current stage of the research), scrutinized according to suitable taxonomies, resulted in consistent results as emerging by a χ^2 test. Therefore, a first set of guidelines has been extracted, so that it is possible to propose a new profile of values with enhanced probability of market success by following the emerging indications.

The reported examples about a business failure (Motorola Iridium) and success (Nintendo Wii), for which substantial dissimilarities and affinities have been individuated with reference to the arisen guidelines, show how the results of the present research can provide reliable indications for NVP initiatives. Such positive feedback encourages surveys of case studies in order to strengthen the definition of the New Value Proposition Guidelines. An extended analysis could be performed of a considerable amount of NVP cases, which have faced unambiguous triumph or failure. Expected outcomes of future studies include the definition of prioritizing criteria for the selection of the most robust recommendations. Further on, the results of the whole survey could be employed to extract metrics for anticipating the success likelihood of original value profiles.

A further key task to be accomplished is the definition of a validation procedure for the proposed guidelines through industrial tests to assess the usability and the reliability of the indications originated by the performed analysis and by future research.

Eventually, the work could be favourably expanded by taking into account additional criteria and taxonomies through which characterizing NVP experiences and business model redesigns, e.g. the Kano model for the involved product and service attributes, Maslow hierarchy of needs, metrics to assess the creativity of innovation initiatives.

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Towards the fine-tuning of a predictive Kano model for supporting product and service design

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Kano's theory analyses only the 'current situation' concerning the extent of customer satisfaction, which results from fulfilling monitored product/service attributes. Such an issue hinders the exploitation of Kano surveys for long-time design projects. On the other hand, trends regarding the shift of quality attributes reported in literature are not supported by rigorous research. In order to highlight evidence about changes in the main drivers for customer satisfaction, the authors have individuated and subsequently examined surveys of three analogous products or services performed by different research groups. The use of a quantitative reference model linking the performance of quality attributes to the ensuing satisfaction provides a clear picture of the transformation occurring within the role played by a plurality of customer requirements. The results of the investigation show remarkable differences in the evolution of quality attributes and point out new needs for the organisation of an experiment to validate the existing hypotheses that concern the transformation of Kano categories. More specifically, the paper stresses the importance of performing repeated tests with the same group of customers, paying attention to industrial sectors where performance is progressing quickly, considering uncertainties related to the output of Kano surveys.

Keywords: Kano's theory; dynamics of Kano categories; quantitative Kano model; product/service design

1. Introduction

The Kano model of customer satisfaction (or 'of attractive quality' as reported in several sources), developed in the 1980s (Kano, Seraku, Takahashi, & Tsuji, 1984), ranks among the most powerful and popular tools to scrutinise the contribution of product/service features within the overall generation of value for consumers (e.g. Berger et al., 1993; Löfgren & Witell, 2008).

Kano's theory has challenged the idea of a linear relationship between the offering level of any product feature and the extent of customer satisfaction that is consequently generated, as highlighted, for instance, by Tsai, Chen, Chan, and Lin (2011). The model subdivides the most valuable product attributes into three categories (must-be, attractive, one-dimensional). These classes show dissimilar and asymmetrical impacts on the capability to generate customer satisfaction and avoid severe discontent (see Figure 1 for the sake of clarity). Additional categories are represented by the following quality attributes:

- indifferent, playing a limited role in the delivery of customer satisfaction;
- questionable, for which the relationship between performance and consumer appreciation is unclear;
- reverse, where its presence contributes to dislike.

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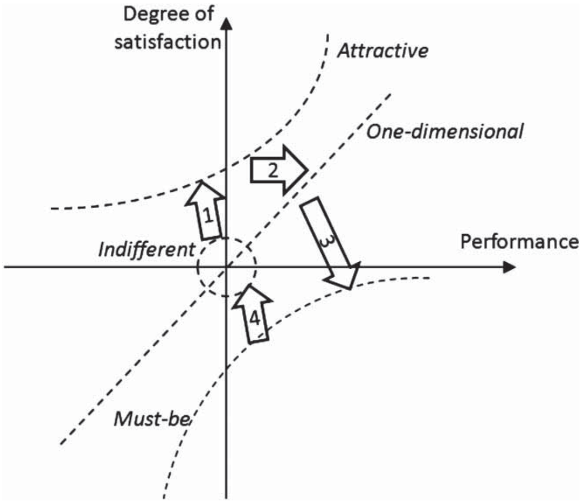

Figure 1. Representation of the dynamic model concerning successful Kano quality attributes.

Classification is performed by exploiting the results of ad-hoc customer interviews aimed at revealing the appreciation level of products and services when a specific need is either met or conversely unfulfilled.

The intuition of non-linear relationships between performance and customer value has led towards the development of tools for supporting decisions benefitting from Kano's theory (Chen & Chuan, 2011; Delice & Güngör, 2009; Rejeb, Boly, & Morel-Guimaraes, 2011). However, such contributions do not aid in tackling design decisions in projects with a long-time horizon. On the other hand, according to the authors' vision, the dispersed knowledge of the Kano model could be exploited to build advanced models applying to long-term New Product Development initiatives. To such an aim, few proposals exploit the hypotheses of evolving quality attributes according to a set of predetermined paths. These patterns have been conceived by Kano (2001) and require further investigation and experimentation.

In this context, the present paper attempts to obtain additional knowledge from the growing amount of literature (Luor, Lu, Chien, & Wu, 2012) that reports case studies about the employment of the Kano model. More specifically, the objective of the investigation consists in evaluating the reliability of evolutionary hypotheses of quality attributes. As better motivated in the following section, these patterns and the proposals about quantitative Kano curves represent the topics of major interest for building decision support systems capable of anticipating the future value of new products or services. Section 3 proposes a roadmap to exploit literary resources for the purpose of extracting empirical evidence regarding the reliability of evolutionary Kano models. The results of the investigation are contextually illustrated and the extracted data are analysed more closely by means of available quantitative models. Whereas Section 4 discusses the emerging results and further analyses the limitations due to the use of data extracted from the literature, the concluding remarks are entrusted to Section 5.

2. Open issues to build a quantitative forecasting Kano model

The literature witnesses open issues and misalignments among the scholars with respect to relevant aspects that concern the employment of the Kano model, its scope and the reliability of its developments. Some researchers put directly into question the actual capability of Kano theory to support decisions within product development projects (Wu & Wang, 2012; Xu, Jiao, Yang, & Helander, 2009). The disputed questions include, among others, the definition of the set of product features to be assessed through the Kano framework, the ways to associate each attribute with its pertinent category (Chen & Lee, 2009; Mikulić & Prebežac, 2011), the acceptability of quantitative models relating performance and satisfaction. The last item represents a crucial aspect in light of building systems for supporting decisions in industry, since quantitative models better support the selection of the most valuable alternatives.

Indeed, within the general purpose of the present work, the most desirable result would consist in a model for computing the future share of customer value provided by the fulfilment of each attribute. Such a system would then be capable of guiding the choices of companies by individuating the most promising investments.

Such an outcome is, however, hindered by the recalled misalignments towards a shared quantitative Kano model viable to describe a static situation; a current lack of a Kano toolkit, according to Zhang, Auriol, Eres, and Baron (2013). In this sense, the first attempt to compensate for this lack has been the use of the adjusted improving ratio, suggested by Tan and Shen (2000). It allows for the consideration, within quality function deployment (QFD), of the different performance/satisfaction trajectories of quality attributes. Such a proposal, of quantitative and evolutionary Kano models, represent those topics which impact, to the greatest extent, the possibility of creating the desired forecasting model. Hence, these will be separately discussed in the following subsections.

For the sake of clarity, some basic concepts included in the classic version of the Kano model (see e.g. Berger et al., 1993) are taken for granted in the remainder of the article. More specifically, no explanation is provided for the coefficients standing for the degree of Customer Satisfaction (CS) and Dissatisfaction (DS), as well as for the way they are calculated.

2.1 *Adjusted improving ratio as a means to introduce asymmetry of satisfaction–performance*

The Kano concept of non-linear dependence between the enhancement of product performance and the growth of customer satisfaction has been exploited in the context of QFD. The objective of matching Kano's theory and QFD is to consider dissimilar competitive advantages resulting from increasing the offering level of any attribute. The most common approach is the recalled adjusted improving ratio, i.e. a differentiated increase in satisfaction provoked by an identical shift of product performance according to its representative Kano category (i.e. attractive, one-dimensional or must-be). From a mathematical viewpoint, the above adjustment stands in a varying exponent (applied to the ratio between the performance of two product variants in order to derive the relative increase in performance. According to (Tan & Shen, 2000) it results that:

$$\mathrm{IR}_{\mathrm{adj}} = \frac{s_1}{s_0} = \left(\frac{p_1}{p_0}\right)^{1/k}, \tag{1}$$

where:

- $\mathrm{IR}_{\mathrm{adj}}$ is the actual adjusted improving ratio;
- s_1 and s_0 represent the levels of satisfaction arising from new and actual solutions;

- p_1 and p_0 stand for the matching performances with respect to the investigated customer requirement;
- k is the corrective factor depending on the corresponding Kano category ('1/2', '1' and '2' for must-be, one-dimensional and attractive attributes, respectively).

Such a correction arises by considering the shape of classic satisfaction–performance curves depicting the Kano categories; indeed, the linearity of one-dimensional attributes determines no adjustment.

Hsu, Chang, Wang, and Lin (2007) multiply the so-formulated IR_{adj} and the raw importance of product attributes to determine the extent of the benefits arising from the increase of performance. The adjusted improving ratios are further employed in Garibay, Gutiérrez, and Figueroa (2010) to determine the major priorities of services redesign.

An alternative way of adjusting the improving ratio with respect to the original proposal is reported in Chaudha, Jain, Singh, and Mishra (2011), which takes into account CS and DS coefficients in addition to the characterisation of attributes through the Kano categories.

2.2 *Hypotheses to quantitatively interpret the characteristic curves of Kano categories*

In recent years, some models have been proposed and implemented in more complex optimisation methods which relate satisfaction and performance by means of mathematical functions.

For instance, Földesi, Kóczy, and Botzheim (2007) employ a model which assigns an exponent to the variable standing for the performance of the customer requirement. The exponent is determined by the associated quality attribute, while its variability, according to customers' opinion, is taken into account by extending the Kano model through fuzzy systems.

Tontini and Silveira (2007), by blending cues from Kano's theory and importance performance analysis (IPA), describe the relationship between perceived satisfaction and the offering level of product features through broken lines. The slope of the lines changes at the point depicting the performance of the investigated service at the current standard. The idea of extrapolating the curves through broken lines is assumed also in the 'piecewise regression' model (Xi, Lee, Teng, & Lin, 2010). The latter observes three different slopes by considering the satisfaction level at minimum, maximum and two intermediate performance degrees.

Wang and Ji (2010) adhere to the shape of qualitative Kano curves by using exponential functions for non-linear quality attributes. However, their model differs from the original design of the curves, since all kinds of customer requirements are deemed to impact the capability to generate satisfaction and avoid dissatisfaction. Indeed, the extent of dissatisfaction and satisfaction represents the extremes of the curves. In other words, they stand for the conditions of minimum and maximum performance with reference to the treated quality factors. On the other hand, Borgianni, Cascini, and Rotini (2011) depict the curves by assigning, just to one-dimensional product features, the possibility of influencing the perception of satisfaction and discontent, regarded as very different dimensions of value within the re-engineering of industrial processes. The extremes of the functions depend on the importance level assigned to each customer requirement, while the shape of the curves reflects the proposal illustrated in Tan and Shen (2000).

Ultimately, it is possible to assess that a different kind of information is required to build the diagrams pertaining to the Kano-wise models devoted to quantitatively interpreting the role of customer requirements in determining the appreciation of a product. The proposals to be considered for such a purpose (Borgianni et al. 2011; Földesi et al., 2007; Tontini & Silveira, 2007; Wang & Ji, 2010; Xi et al., 2010) include, overall, the need of assessing (see Table 1 for major detail of the single contributions):

- the Kano category attributed to each customer requirement;
- the share of customer answers which delineate a certain Kano category;
- the quantity of respondents declaring their actual state of satisfaction or discontentment with respect to any product characteristic;
- the importance related to each customer requirement;
- the computation of CS and DS;
- the performance (and the matching satisfaction degrees) of the current product design, of best and worst options, intermediate values of offering levels regarding the quality attributes.

2.3 *Expected evolution of Kano categories*

Besides the missing convergence on quantitative proposals, the potential of the Kano model to support strategic product development decisions is affected by the often-disregarded dynamics of customer preferences, whose impact is extensively underlined in Chong and Chen (2010). In this sense, as already mentioned in the Introduction, hypotheses about the evolutionary nature of quality attributes can partially represent a cue for filling the gap.

Table 1. Quantitative Kano models and required information to build the diagrams.

Model	Attributed Kano category	Share of respondents for each Kano category	Relevance	CS/DS indexes	Multiple performance levels and matching satisfaction
Fuzzy extension of the Kano model (Földesi et al., 2007)	No	Yes	No	No	Yes
Kano + IPA (Tontini & Silveira, 2007)	No	No	No	Yes, in a modified form	Yes
Piecewise regression (Xi et al., 2010)	No	No	No	No	Yes
S–CR relationship functions (Wang & Ji, 2010)	Yes	No	No	Yes	No
Satisfaction equations (Borgianni et al., 2011)	Yes	No	Yes	No	No

Löfgren, Witell, and Gustafsson (2011), on the basis of the findings reported in Kano (2001), claim that the changes occurring to quality attributes can observe specific behaviours. Successful product attributes follow a cyclical pattern that initially foresees the shift from indifferent to attractive quality, once customers start to perceive the exciting value of a given product attribute. After this, consumers get used to the benefits ensuing from the fulfilment of such product features and the Kano category switches towards one-dimensional (and subsequently must-be) quality. In a certain sense, customer requirements tend to decrease their capability to generate satisfaction, and their fulfilment is devoted to maximally avoiding harm. It can eventually happen that radical innovations of the product determine the obsolescence of previously relevant characteristics. In these cases, certain attributes produce no more value for the customer. Hence, a novel transformation is observed that leads towards indifferent quality. Figure 1, which is reported for the sake of clarity, illustrates such a cycle in a graphical form.

Several sources dealing with the dynamics of Kano categories acknowledge only the patterns of successful quality attributes. Their evolutionary mechanism is confirmed in several contributions (e.g. Chaudha et al., 2011) and is motivated by the changes occurring as a result of accumulated user experience (Nilsson-Witell & Fundin, 2005). The dynamic logic of quality attributes is employed within tools to support product development by Sakao (2009) and Raharjo, Brombacher, Goh, and Bergman (2010). The former provides an additional graph depicting possible modifications for the surveyed product characteristics in the field of eco-design. The latter show an effective integration of the evolutionary logic, though the example is limited by the employment of illustrative and hypothetical data, giving rise to poor reliability of the proposed methodology. On the other hand, Zhao and Dholakia (2009) shed light on different shifts occurring for different kinds of users and hence remark mismatches with the dynamics of successful quality attributes.

The most acknowledged alternative cycles are still reported in Löfgren et al. (2011), which highlights the presence of flavour-of-the-month and stable Kano categories. The former rapidly turn from indifferent to one-dimensional and back to indifferent quality, standing for those characteristics of seasonal products contributing to satisfaction for a short period of time. The latter individuate those features whose role in determining satisfaction does not change over time and that are consequently characterised by longer life-cycles. Therefore, these quality attributes do not observe any transformation, unlike the other groups. Also in Löfgren et al. (2011), it is shown that just 4 customer requirements of 24 regarding the packaging industry do not follow any of the hypothesised patterns, with a wide majority of stable quality attributes.

2.4 *Remarks about the surveyed issues concerning the Kano model*

Criteria based solely on improving ratios results are unsuitable for the final scope of the present research (i.e. a system quantitatively estimating customer value of future product/services). This is due to the disregard of the asymmetric roles of customer satisfaction and dissatisfaction within the overall consideration of user value (Mittal, Ross, & Baldasare, 1998). Such limitation is overcome by the models described in Section 2.2, with the exception of the proposal reported by Földesi et al. (2007). At the same time, Table 1 shows how the proposed quantitative Kano models require different types of data in order to relate product performance and customer satisfaction. Such an aspect relentlessly impacts the applicability of these frameworks within the insightful analyses of products and services presented in the next section.

The dynamic models of quality attributes result then, in a chance to build a support system capable of expanding the employment field of the Kano model. Nevertheless, their reliability results are arguable, since no validation has been performed, nor have the constraints for their application been clarified. According to the authors' knowledge, no within-subjects repeated measures design, commonly entrusted to assess changes over time, has been employed to verify the effectiveness and further limitations of evolutionary Kano categories. Such a test would allow the evaluation of modifications in consumers' perception. It requires analysing a set of customer requirements pertaining to a given product or service in different moments and subsequently assessing the actual influence of time and accumulated experience.

With reference to the recalled lacks, the paper is devoted to better investigating the dynamic nature of quality attributes and providing an investigation approach to supporting the consistency of evolutionary hypotheses.

3. Outcomes of the investigation in different industrial sectors

The authors are aware of the difficulties in designing and carrying out a vast and long-lasting experiment, such as a within-subject test involving sufficient people to be considered statistically sound. In these circumstances, preliminary information can be attained by comparing the results of available surveys regarding the attributes of a specific product or service through the lenses of the Kano model in different periods. Such an approach may suffer from several biases, in terms of possible differences among the analyses with respect to boundary conditions, procedures through which the surveys have been conducted, samples of interviewed customers, and explored product features. Nevertheless, by reviewing industrial sectors for which a number of Kano investigations have been carried out, the authors try to highlight aspects to be further scrutinised through more rigorous tests.

With this objective, the authors have browsed the literature (more specifically journal and conference articles) to individuate papers reporting in detail the outcomes of surveys performed by means of the theory of attractive quality. The review revealed four sectors, including surveys of similar products or services capable of being compared. However, a case regarding hotel services is not exploitable, since comparable Kano surveys were performed roughly at the same time (if the publication dates of the papers are considered; Lin, Tsai, Wang, & Su, 2011; Yang, Jou, & Cheng, 2011). The remaining examples are reported in Sections 4.1–4.3. In the first instance, the modifications of Kano categories have been observed, with the aim of evaluating the compliance with at least one evolutionary model. Subsequently, the quantitative Kano framework reported in Wang and Ji (2010) has been employed to infer further empirical evidence through graphical outputs.

3.1 *Notebooks*

Two papers have been retrieved by the authors that expose the results of Kano surveys in which consumers of notebooks participated. The older manuscript (Tang & Huang, 2004) aims at investigating the different perceptions of customers, manufacturers and dealers in terms of the role played by 28 product attributes in generating customer satisfaction. Beyond some dozens of participants belonging to the other groups of stakeholders, the questionnaires were responded to by a sample of 584 customers of computer shops in Taipei, including a significant amount of young people. In the more recent contribution by Wang and Ji (2010), quantitative Kano curves are built on the basis of the answers provided by 125 undergraduate students, likely from Hong Kong (the provenience of the authors of the paper), in an investigation concerning 16 notebook attributes.

The interviewed samples show several affinities (e.g. consumers from a vibrant Asian city, mostly of young age), but the sets of investigated product attributes hardly overlap. Table 2 reports the similar attributes individuated by the authors and the matching Kano classifications according to the outcomes of the investigations. The last column of the Table reports whether any of the alternative evolutionary models described in Kano (2001) and Löfgren et al. (2011) fit the comparison between the first and the second surveys. Whereas product characteristics have observed no change in the Kano category, the occurrence of stable quality attributes has been indicated, although the presence of successful Kano categories showing a slow pace of transformation could be hypothesised. The same criteria are also applied in Sections 3.2 and 3.3.

In brief, the information presented in the table remarks that half of the product attributes infringe the patterns expected by any of the considered evolutionary Kano models. Whereas two categories of customer requirements stay unchanged, a product property (i.e. design) observes a transformation compliant with the hypothesised dynamics of successful attributes.

3.2 *Websites*

In Tan and Shen (2000), a case study regarding the quality of websites is employed to illustrate a methodology that integrates QFD and Kano theory. Unfortunately, no information is provided with respect to the sample of individuals that performed the evaluation of eight customer requirements. The same quality factors, in addition to four new emerging characteristics, are taken into account in the research reported in Chaudha et al. (2011), which involved the interview of 53 regular Internet users.[1] As already reported, Chaudha et al.

Table 2. Common attributes between two surveys, published in 2004 and 2010, respectively, and involving notebook consumers.

Attribute	Definition in (Tang & Huang, 2004)	Definition in (Wang & Ji, 2010)	Kano category in (Tang & Huang, 2004)	Kano category in (Wang & Ji, 2010)	Suitable model
Lightness	Product weight and size	Light and mobile	Must-be	One-dimensional	*None*
Design	Outlook design	Stylish design	Indifferent	Attractive	*Successful*
Memory capacity	Capacity of saving device (memory)	Large storage	Must-be	Must-be	*Stable*
Speed	Executing speed of CPU	High computing speed	One-dimensional	One-dimensional	*Stable*
Expandability	Function expandability	Expandable device	Must-be	Attractive	*None*
Repairing service	Repair and service by dealer after-sales	Replacement and repair services	Must-be	One-dimensional	*None*

(2011) discuss the comparison of the obtained results with those illustrated in Tan and Shen (2000) and the evolutionary concept of the Kano model is largely confirmed. Only the attribute named 'interesting web page' violates the cycle predicted by the models for the transformation of Kano categories. Nevertheless, the illustrative purposes of the case study exposed in Tan and Shen (2000) and the lack of any information of variability and uncertainty make the comparison poorly reliable.

In a previous research with respect to Chaudha et al. (2011), Zhang and von Dran (2001) aim at pinpointing the differences between websites with different purposes. The results of the investigation are presented, revealing the perception of 42 features by 60 users frequently surfing the Internet. Such outcomes are worth comparing to those arising from Chaudha et al. (2011), since both studies report surveys about general-purpose information web pages, and the sample sizes of the respondents to questionnaires are likely to provide reliable data. Once again the lists of the investigated attributes are substantially different and the authors have extrapolated those requirements and properties which are supposed to stimulate similar dimensions of value (Table 3).

The above results individuate no conflict with respect to the cycles foreseen by the evolutionary Kano models.

3.3 *The banking industry*

Two surveys from different periods investigating the drivers of satisfaction for customers of bank branches in Asia have been individuated. The older paper (Bhattacharyya & Rahman, 2004) reports the answers of 100 customers of a bank branch in India, who provided their perception of 39 potential triggers of customer satisfaction. The more recent study (Zarei, Hemati, & Rafeeian, 2012) describes a survey involving 125 clients of an Iranian bank branch, who expressed their opinion with respect to 21 service features. Although the sample of surveyed customer requirements strongly differs, six attributes (Table 4) have been identified which concern very similar characteristics of the offered service.

Such attributes, except for the last, comply with the guidelines offered by the evolutionary cycles under investigation.

Table 3. Common attributes between two surveys, published in 2001 and 2011, respectively, and involving the design of websites.

Attribute	Definition in (Zhang & von Dran, 2001)	Definition in (Chaudha et al., 2011)	Kano category in (Zhang & von Dran, 2001)	Kano category in (Chaudha et al., 2011)	Suitable model
Readability of the web page	Sharp displays	Reading of text	One-dimensional	Must-be	*Successful*
Quantity of information	Appropriate detail level of information	Sufficient information	One-dimensional	Must-be	*Successful*
Intuitiveness of information presentation	Structure of information presentation is logical	Locating of information	One-dimensional	One-dimensional	*Stable*

Table 4. Common attributes between two surveys, published in 2004 and 2012, respectively, and involving bank branches.

Attribute	Definition in (Bhattacharyya & Rahman, 2004)	Definition in (Zarei et al., 2012)	Kano category in (Bhattacharyya & Rahman, 2004)	Kano category in (Zarei et al., 2012)	Suitable model
Quickness of the services	Bank provides prompt service	The rapidity of giving services	One-dimensional	Must-be	*Successful*
Cheapness of the provided services	Low charges for banking services, i.e. issue of draft and overdraft charges	The cost of receiving bank services	One-dimensional	Must-be	*Successful*
Security	Bank keeps account holders' documents safely	Security in using of bank services	Must-be	Must-be	*Stable*
Branch environment	Bank has a good ambience	Tidiness of branches	Indifferent	Attractive	*Successful*
Electronic facilities	ATM facility	Using the electronic facilities	One-dimensional	Must-be	*Successful*
Accessibility of the branch	Bank is located at a convenient place	Place position of branches	Must-be	Attractive	*None*

3.4 *Comparing the outcomes of the surveys through quantitative Kano models*

The similar attributes belonging to surveys from different periods are viable to be analysed in greater detail through available quantitative Kano models, in order to shed light on further evidence thanks to the employment of graphical outputs. The selection of the quantitative models to be exploited has to be made according to the available information reported in the Kano surveys compared in Sections 3.1, 3.2 and 3.3. Beyond the most representative Kano category, all of them illustrate, for each competing factor, CS and DS coefficients or sufficient data to compute them, as reported in Table 5. Tang and Huang (2004) is a partial exception to this condition, since it provides richer information for only a subset of customer requirements.

Conversely, the quantity of designations for each Kano category, relevance indexes and satisfaction assessments at diverse quality levels are not included in the papers under investigation, or at least in a great part of them. Given the current situation, and according to Table 1, just the quantitative model described in Wang and Ji (2010) can be employed with the objective of graphically comparing the representative Kano curves belonging to different periods. A consistent limitation of such a model is represented by the missing means to represent Indifferent product attributes. This aspect does not allow the depiction of the transformations for the design of notebooks and the environment of bank branches (see Tables 2 and 4).

The extrapolation of the pairs of curves pertaining to the product attributes is then feasible only in 12 cases: the matching Figures A1–A12 are reported in the appendix. In all of these, dotted lines represent the relationship between performance and customer satisfaction or dissatisfaction (whereas the value of the ordinate is lower than 0) for the situation of previous research; conversely, continuous curves refer to the same quantitative link with respect to later surveys.

Table 5. Transformation of CS and DS indexes for the product/service attributes extrapolated from research conducted at different times.

Product or service	Attribute	CS in the first research	CS in the second research	DS in the first research	DS in the second research
Notebook	Lightness	0.39	0.60	−0.76	−0.66
	Design	0.32	0.66	−0.24	−0.32
	Memory capacity	0.37	0.43	−0.61	−0.58
	Speed	0.29	0.59	−0.74	−0.71
	Expandability	0.18	0.56	−0.84	−0.23
	Repairing service	Missing data	0.54	Missing data	−0.67
Web page	Readability of the web page	0.60	0.44	−0.82	−0.69
	Quantity of information	0.72	0.41	−0.76	−0.71
	Intuitiveness of information presentation	0.63	0.53	−0.91	−0.59
Bank branches	Quickness of the services	0.58	0.18	−0.88	−0.98
	Cheapness of the provided services	0.62	0.34	−0.62	−0.93
	Security	0.48	0.09	−0.96	−0.99
	Branch environment	0.81	0.64	−0.70	−0.15
	Electronic facilities	0.58	0.25	−0.88	−0.91
	Accessibility of the branch	0.32	0.78	−0.86	−0.14

4. Discussion of the results

The built quantitative curves allow the highlight of circumstances otherwise neglected by the unique observation of the transformation of Kano categories.

The case concerning the changing role played by the product attributes of the notebook (Figures A1–A4) reveals how no mapped factor markedly follows the increase of customer dissatisfaction and the diminishment of satisfaction generated by poor and optimal qualitative levels, respectively. This phenomenon is particularly evident with respect to speed (although reported as a stable quality attribute) and expandability of the notebook (infringing any evolutionary model). On the other hand, the lightness of the notebook seems to keep a quite constant relationship between performance and consequent customer value, despite the unexpected change of Kano category. Whereas a slightly more pronounced distinction seems to emerge just for high offering levels, the exploration of memory capacity reveals marginal differences in the whole field of observation. It then looks like a stable quality attribute, rather than a successful Kano category with a low pace of change. This evaluation is supported, in the authors' vision, by considering the memory of any computer as a basic feature that could be replaced only by radical innovations in the industry; not requiring any more space to store data.

A possible cause of the above misalignments with respect to the foreseen results may lie in the peculiarities of the ICT sector, which observes rapid technological growth. In this sense, surveys taken with a gap of a few years may refer to already-distinct technological eras. For instance, customers have very dissimilar expectations with regard to the speed of computers, even in relatively close time periods. In other words, with reference to the representative satisfaction–performance curves, minimum and maximum offering levels belong to considerably different intervals and, as a consequence, the display of the graphs may be misleading. As a result, the need arises to better define, in the conducted surveys, what the accomplishment or missed fulfilment of the investigated customer requirements represent. In other words, it would be more suitable to indicate actual performance levels on the abscissas of the graphs. With these premises, a switch from qualitative to quantitative Kano models requires, at least in the authors' vision, major rigour in the definition of the quality attributes, their actual degree of fulfilment, and the resulting level of customer satisfaction or discontentment.

The case of the web page is, as already emerging from Section 4, the one showing the smallest incongruence with respect to the evolutionary models. The curves in Figures A5–A7 show globally, in line of tendency, the growing risk arising from poor accurateness in fulfilling the mapped features and a decrement of their capability to generate satisfaction for the user. However, most of the modifications, regardless if they comply or disagree with the expected changes and the presence of successful or stable quality attributes, stand in hardly appreciable transformations (at least according to the adopted quantitative model) and the disregard of uncertainty issues may lead to wrong conclusions.

The example of bank branches presents remarkable affinities with the trends predicted through the evolutionary Kano models. Although uncertainties may play a misleading role also in this case, a majority of attributes observes growing degrees of potential dissatisfaction and a declining capability to provide unexpected value. Such phenomenon is observed also for the stable quality attribute (security), although with a minor intensity if compared to Kano categories classified as successful. In this situation, the accessibility of bank branches plainly represents an exception from all viewpoints. By examining specific branches under investigation and the samples of customers interviewed in Bhattacharyya and Rahman (2004) and Zarei et al. (2012), it emerges that a possible reason for such misalignment lies in the different clientele served by the banks. In the first survey, students from a University campus are interviewed about a very close branch and may not perceive hardships in reaching the bank, as potentially experienced by the second sample constituted by account holders living in a mid-sized town. Such a circumstance, if the authors' hypothesis is correct, remarks the need for employing similar samples of interviewed customers to compare Kano surveys.

Additionally, it has to be highlighted that no examined transformation has followed the classic pattern of flavour-of-the-month quality attributes. Such an issue is likely to be motivated by surveying case studies that do not belong to the world of seasonal products. In other words, the set of available industrial products or services, including a plurality of Kano investigations, can represent a bias in discovering the behaviour of flavour-of-the-month categories.

4.1 *Summary of emerging hypotheses and research questions*

Ultimately, the examination described in the present paper suggests further investigating the following issues or empirical evidence:

- the dynamics of successful quality attributes works as a general tendency with reference to Kano categories observing transformations;
- a non-negligible amount of customer requirements behave like stable quality attributes: for most of them, by observing quantitative Kano curves, the hypothesis of evolving at a different pace seems to be rejected;

- the trend of the growing potential of customer requirements to provoke harm (if unfulfilled) and the diminishing capability to generate satisfaction (if accomplished) observes fluctuations;
- the analysis of customer value through the lenses of Kano theory has to take into account uncertainties which can give rise to misleading conclusions, especially in the recurring cases of slight modifications observed in performance-satisfaction curves;
- a convergence of scholars and practitioners on a rigorous quantitative model would be welcomed in order to avoid biases resulting from wrong mathematical relationships between satisfaction and performance;
- the design of samples for comparative surveys taken at different times has to ensure the absence of diverging demographical factors, viable to impact, to a meaningful extent, the results of the investigation (Shahin & Zairi, 2009); in this sense, within-subject repeated measures experiments are the most reliable strategy;
- an insightful analysis of the role played by product attributes in determining satisfaction has to clarify the range of their plausible offering levels at a certain point within the development history of the treated artefact; the disregard of technological development may lead to pitfalls mistakenly suggesting the infringement of evolutionary Kano models.

5. Conclusions

Given the large set of open issues concerning the extension of Kano's theory, the present paper strives to identify the most severe limitations that hinder a wider diffusion of the model of attractive quality as a tool for decision-making in product/service design. Whereas tasks to maximise customer satisfaction are commonly carried out by means of the Kano model and QFD, long-term strategic product development decisions cannot be currently supported because of ignoring upcoming drivers of customer satisfaction. The present paper claims that the refinement of the Kano toolkit could lead to the achievement of a forecasting instrument for identifying those customer needs capable of generating the greatest extent of satisfaction in the future and thus being prioritised in engineering design tasks requiring long development cycles. More specifically, it is inferred that such a result could be reached by obtaining insightful knowledge about the dynamics of quality attributes and fine-tuning reliable functions relating to performance and satisfaction.

However, the evolutionary hypotheses concerning Kano categories have received, up to now, only empirical confirmation. The authors have individuated, in repeated measures, design tests to be the most suitable way to validate (or reject) the intuitions of the evolutionary Kano model. Nevertheless, before embarking on such a long-lasting and time-consuming experiment, available surveys about similar products or services have been scrutinised and compared in order to gain further evidence. The analysis has included the building of quantitative curves by means of the only model that could be employed, according to the kind of information reported in the described Kano surveys. The whole analysis has pointed out a set of emergences to be verified and research questions requiring wider investigation, as discussed in the preceding section.

The authors would be glad to receive suggestions from other scholars or practitioners about surveys from different periods that have not been retrieved, in order to focus on further research questions and expand the scope of the reported discussions.

Whereas future activities should include the definition of the above, required experiment, candidates are welcome to support the preparation of the tests and to carry out vast surveys in different time periods.

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Note

1. As resulting from private communication with the authors of the cited paper.

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Appendix

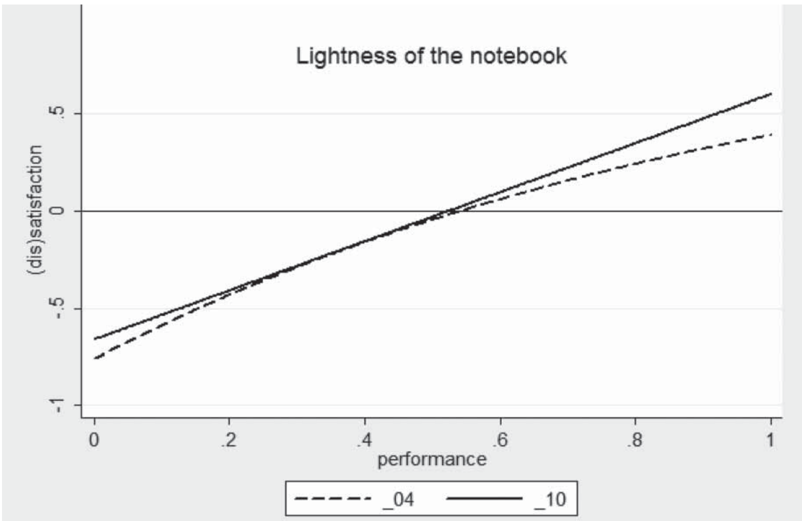
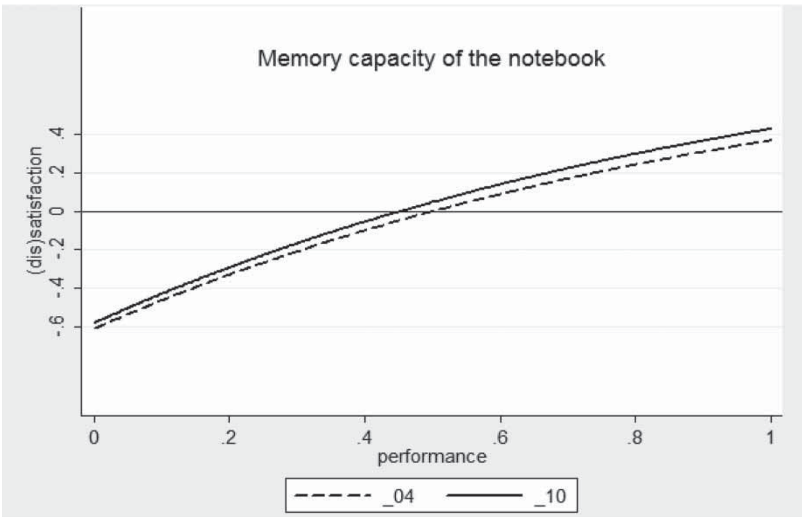


Figure A1. Link between customer satisfaction and the lightness of the notebook in two different researches published in 2004 (dotted line) and 2010 (continuous line), respectively.



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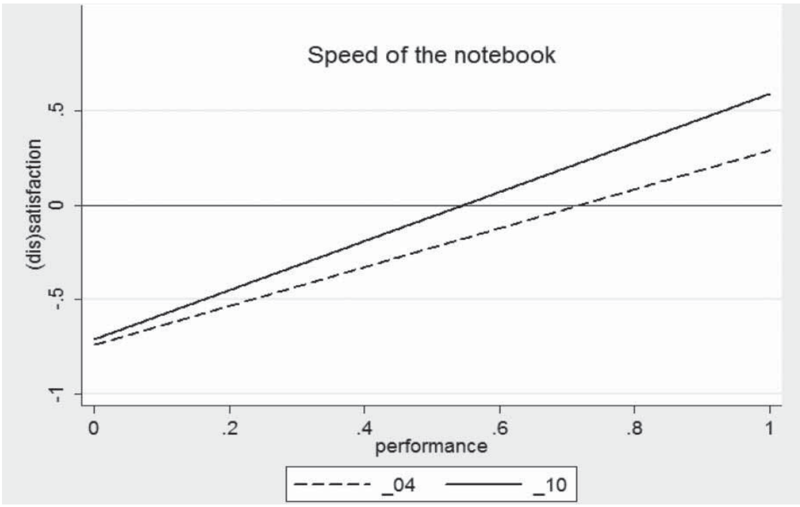

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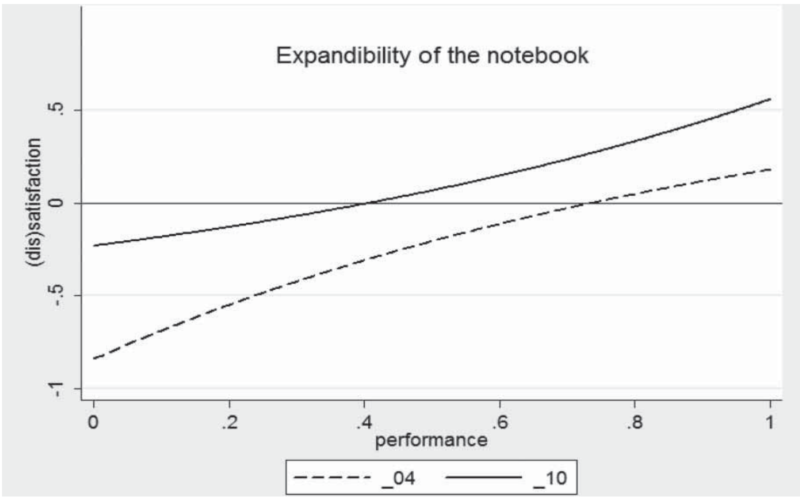

Figure A4. Link between customer satisfaction and the expandability of the notebook in two different researches published in 2004 (dotted line) and 2010 (continuous line), respectively.

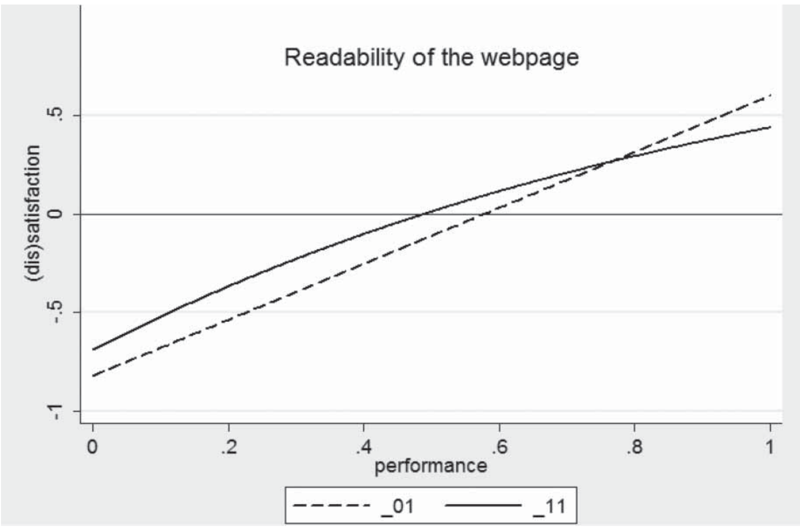

Figure A5. Link between customer satisfaction and the readability of the web page in two different researches published in 2001 (dotted line) and 2011 (continuous line), respectively.

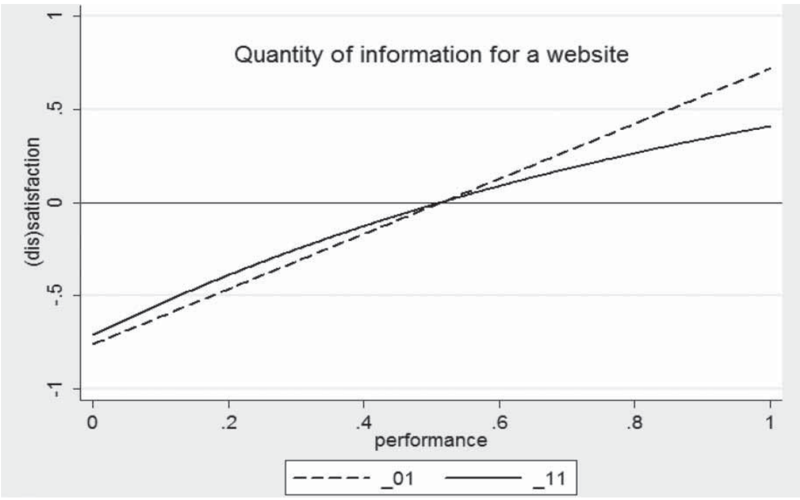

Figure A6. Link between the customer satisfaction provided and the quantity of information for a website in two different researches published in 2001 (dotted line) and 2011 (continuous line), respectively.

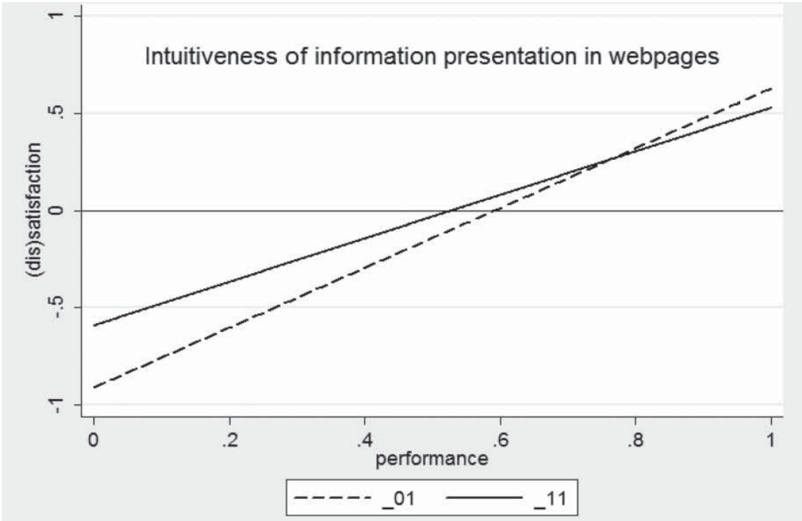

Figure A7. Link between the customer satisfaction provided and the intuitiveness of information presentation for a website in two different researches published in 2001 (dotted line) and 2011 (continuous line), respectively.

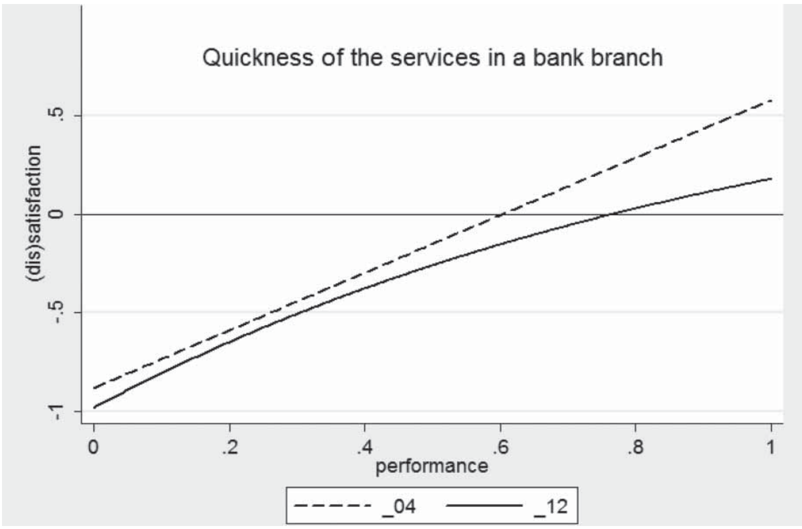

Figure A8. Link between the customer satisfaction provided and the quickness of the services in a bank branch in two different researches published in 2004 (dotted line) and 2012 (continuous line), respectively.

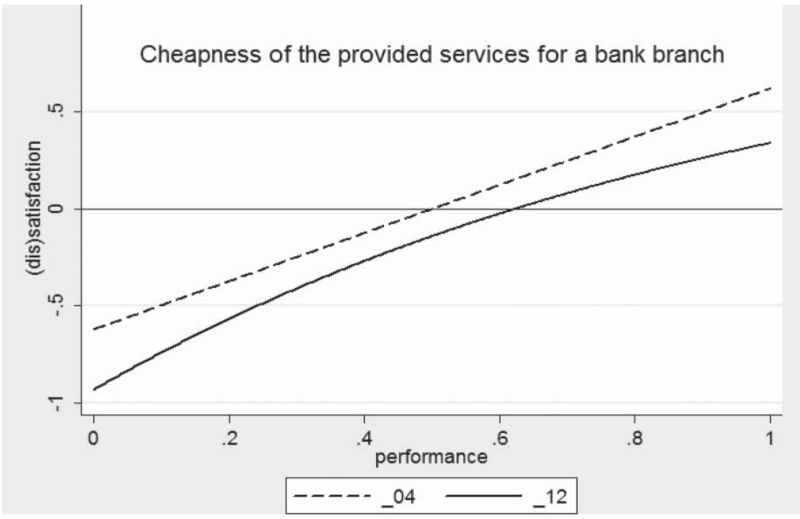

Figure A9. Link between the customer satisfaction provided and the cheapness of the provided services in a bank branch in two different researches published in 2004 (dotted line) and 2012 (continuous line), respectively.

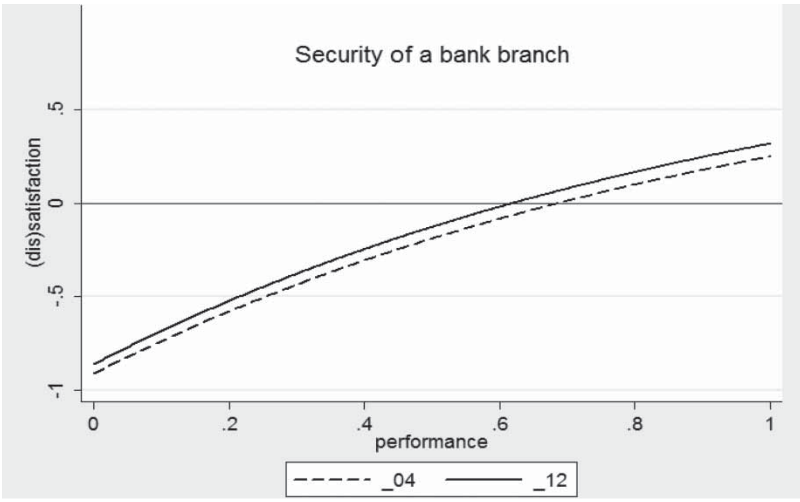

Figure A10. Link between the customer satisfaction provided and the security of a bank branch in two different researches published in 2004 (dotted line) and 2012 (continuous line), respectively.

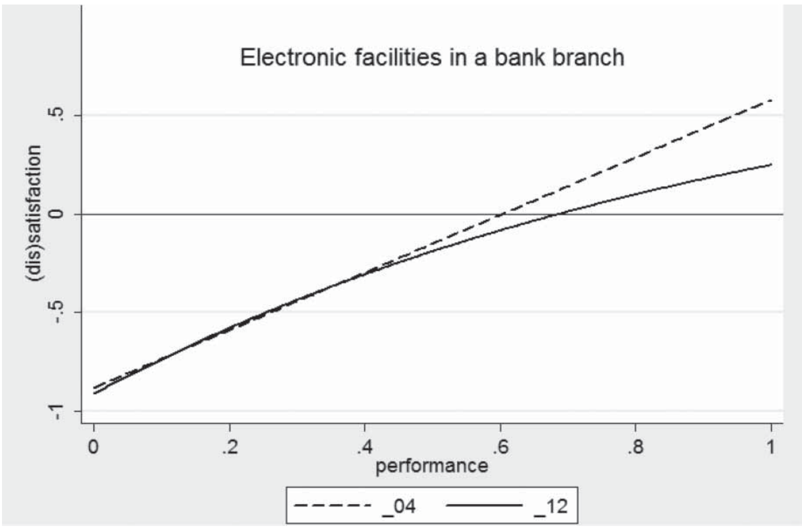

Figure A11. Link between the customer satisfaction provided and diffusion of electronic facilities in a bank branch in two different researches published in 2004 (dotted line) and 2012 (continuous line), respectively.

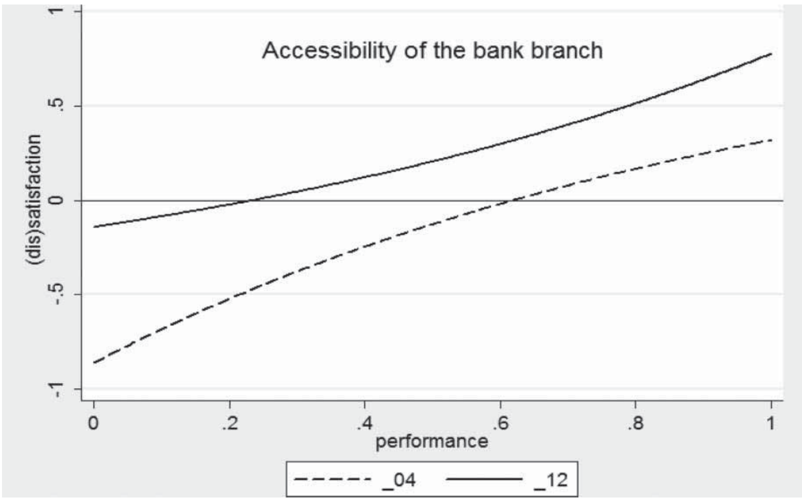

Figure A12. Link between the customer satisfaction provided and the accessibility of the bank branch in two different researches published in 2004 (dotted line) and 2012 (continuous line), respectively.

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Supporting product design by anticipating the success chances of new value profiles

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ABSTRACT

Companies willing to introduce radical innovations have to face the tough task of correctly evaluating manifold aspects concerning the lifecycle of the new products to be launched. In such a circumstance severe difficulties arise because, at the very beginning of the design process, project teams own limited and unreliable information about the performances viable to positively impact value for customers and consequently the commercial success. The present paper suggests an original approach for the anticipatory assessment of the expected market appraisal of a new product profile. The proposed "Value Assessment Metrics" (VAMs) is a tool to estimate the success potential of a new artefact through a balance of its functionalities and features with respect to the alternatives existing in the market. The metrics are defined through an induction process from a large collection of successful innovations and market failures. After reporting the methodological approaches adopted to build the VAMs, the first based on Logistic Regression, the second on Neural Networks, the paper presents their preliminary validation and two example applications to the proposition of an innovative lipstick and a concealed hinge.

1. Introduction

Engineering design methods and techniques are extending their domain of application beyond the limits of the classical stages of product development, i.e. conceptual design, embodiment design, and detailed design. As a result, a systematic and structured approach is more and more needed since the earliest stages of product definition to the follow-up management of after-sale services.

While the design and efficient management of after-sales support functions has become a rather consolidated practice, the so-called "fuzzy front end" of New Product Development (NPD), which concerns the stages from the opportunity identification to the concept definition, is characterized by high market and/or technological uncertainties. Then, the lack of structured means for supporting decision making within the front end of innovation [1] determines a huge waste of resources for developing poor-valued products: market failures are more than 99% of the submitted innovation projects in industry [2].

Not surprisingly, several research lines within the engineering design community are devoted to these topics. Among the others, User-Centred Design dedicates major efforts to understand customer needs through a closer relationship with individuals designated to employ new products. Nevertheless, the phase of needs identification is mostly limited to marketing inputs and to the observation of customers' behaviour so as to elicit the so-called Voice of the Customers (VoC). As already pointed out by several authors, the major limit of an innovation driven by the VoC is that "customers don't know what they want in the future" [3], although to be competitive it is necessary to aim at "being the first to give it to them". Therefore, this approach does not reduce, in principle, the waste of research resources towards poor-valued innovations. On the other hand, targeting innovation projects according to a value-oriented product or service is currently not properly supported by systematic and reliable methods and tools.

Indeed, the typical contribution of engineering design techniques to product innovation is essentially limited to the

Abbreviations: BOS, Blue Ocean Strategy; ERRC, Eliminate Reduce Raise Create; FAF, Four Actions Framework; GDLA, Gradient Descent Learning Algorithm; HF, Harmful Functions; LMBP, Levenberg–Marquardt Back-Propagation; MSE, Mean Squared Error; NN, Neural Networks; NPD, New Product Development; NVP, New Value Proposition; RES, Resources; TRIZ, Theory for Inventive Problem Solving; UF, Useful Functions; VAM, Value Assessment Metrics; VoC, Voice of Customer.

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development of new solutions to already identified problems, while the proposition of new product profiles is just marginally supported. Orawski et al. [4] propose a general model to address three different degrees of product novelty, but the focus is still on the technological aspects of innovation (prototypes and simulations build the basis for its approval), while the assessment of the market potential of an innovative product is not properly included in their model.

A not negligible critical issue related to this deficiency is the lack of integration between the activities of New Value Proposition (NVP), i.e. the definition of original sets of product attributes which can be considered value-wise by the market, and the following design phases for the implementation of such product profile.

The authors' previous work in the field aimed at developing tools to generate innovative profiles of products. Within this area of research, a direction of interest is the systematization of the logic suggested by the Blue Ocean Strategy (BOS), developed by Kim and Mauborgne [5]. BOS is a well-known consulting strategy for value innovation, just marginally relevant from the scientific point of view, but noticeably spread in the industry thanks to its beneficial support to entrepreneurial practice [6]. It orientates the product development endeavours towards the creation of unprecedented mixes of competing factors and their related levels of fulfilment, graphically depicted through the so-called Value Curve [7]. In a recent paper [8], the authors have proposed a classification of the product attributes according to TRIZ functional features, as a means to identify systematic guidelines for defining new market opportunities. The original contribution of the present manuscript is the combined analysis of successful case studies and market failures as a way to build a model for estimating the perceived value of a product profile. Thus, instead of anticipating the commercial opportunities of innovative items through the simulation of market shares and customers' behaviour, as classically performed in industry, the here presented approach aims at predicting success chances on the basis of the pursued product development strategies with respect to industrial standards. The overall scope of the research is then to assess the potential success of all the new product development experiences that deviate from current standards in order to provide new value for customers.

The paper is organized as follows. The next section presents a state of the art analysis within the perspective of needs identification for NVP, references the previous research outcomes achieved by the authors and illustrates a more specific description of the objectives of the present study. Section 3 describes the methodological approach to select and analyse case studies about market success stories and failures. Then, two alternative models are investigated to check the possibility to build a metric for assessing the value of an innovative product or service profile: Logistic Regression and Neural Networks. The validity of the proposed metrics is then verified in section 4 by means of two case studies, one related to a hypothetical innovative lipstick investigated through a simulated customers' survey, the second reporting a real industrial application in the field of concealed hinges. The discussion (Section 5) reports the authors' vision to integrate the proposed contribution within the NPD cycle, with potential interactions with inventive design methods and tools. The conclusions are drawn in Section 6 that closes the article.

2. Overview of innovation methods based on customer needs and perceived value

The identification and the fulfilment of customers' needs represent a crucial step for designing and developing successful products [9]. Regardless of the recalled limitations of VoC tasks, the wide involvement of customers into design activities plays a significant role with the aim of obtaining new ideas and suggestions. Since the 1980s, the literature reports experiences regarding the employment of lead users into the product development phases [10]. At the current state of design research regarding the human needs and, consequently, the engineering requirements to be fulfilled for their achievement, the following themes are broadly debated:

- the tools to be employed for the individuation of seeded needs, which allows to achieve strategies offering superior customer value [11];
- the task of correlating emerging needs and design specifications, that is also affected by the ambiguous terminology of the domain [12];
- the necessity to represent human needs and their implication into acknowledged design frameworks and models [13];
- the choice regarding which customer requirements to be addressed and which new functionalities to introduce in order to obtain relevant competitive advantages [14].

2.1. The dynamics of user preferences

A further issue regards the dynamics concerning the modifications of user preferences and customer perceived satisfaction. In this context it is well established that both technological innovation [15] and market conditions [16] consistently influence the emerging of new demands and changes in consumers' preferences. The interplay between technical and business aspects still has not been explained through an integrated and harmonized model; nevertheless, both domains share the vision about evolution schemes depicted through long periods characterized by incremental innovations interrupted by product breakthroughs, causing consistent market turbulences [17,18]. Such discontinuities act as a trigger for remarkable modifications within the bundles of customer requirements to be fulfilled and their role played within the perceived satisfaction of the products in the marketplace.

If this mechanism represents a chance to fulfil new business ideas, on the other hand it results in a further hurdle for correctly satisfying the user needs at the right time. The capability to detect and anticipate customer preferences would thus result in a substantial competitive advantage within NPD initiatives, with a great influence on the front-end stage, whereas the most impacting decisions about the design are undertaken [19].

Moreover, several products and services have to address intricate networks of demands, often conflicting to each other. The buyer and the user are not necessarily the same person, as well as the actor (s) that will ultimately benefit from the product might be different from either the buyer or the user [20]. With this regard, the authors refer to the user as the individual or organization that directly interacts, manages or governs the system under investigation. Therefore, if the innovative product, for instance, is a train, the buyer is the railway company, the user is the train driver, but the passengers are the direct beneficiaries of the product itself, being the recipients of the transportation service. Additionally, in other circumstances, buyers can also be influenced by other stakeholders, such as installers or vendors.

Within this perspective, while the attempts of formulating laws regarding the development of customer needs, e.g. the proposal advanced by Petrov [21], have resulted in poor reliability and/or industrial applicability, the most acknowledged frameworks that link user demands, product attributes and originated benefits are viable to describe just a static frame of the evolving picture.

From this viewpoint Kano model [22] stands for a remarkably useful instrument to point out the current market situation for a given product or service and to investigate the potential appeal of new attributes [23,24]. Moreover, some scholars, e.g. [25], have depicted an evolving logic of the Kano categories of customer requirements, motivated by the consolidation of consumers' habits and expectations. However, both the original model and its integration do not hold any means to suggest new product requirements and new needs to be served, being addressed just at estimating their capability of impacting customer satisfaction, after they have been separately identified.

2.2. Overview of approaches to meet customer needs

The branch of literature dedicated to the identification of new customer needs is rich of approaches, e.g. mass customization, servitization, etc., which provide acknowledged directions about general trends to be pursued, but still there is no general systematic framework to support this task. For instance, Du et al. [26] propose a tool to support the need of manufacturing personalized products by integrating such task within design cycles on the basis of the mass customization phenomenon (rooted in the 1990s and then observing a boom at the beginning of the new millennium). As well, great attention has been attributed in the last decade to Product Service Systems, which aim at generating a unique mix of tangible products and intangible services, designed in a synergic way by the enterprise and the buyers in order to satisfy customer needs [27].

In the field of product development, the consistent advantages emerging by the codification of latent needs is fully understood, but, on the other hand, systematic procedures for developing innovative products characterized by leaps in customer value have not been fine-tuned yet. Whereas surveys and collections of consumers' opinions represent, as underlined in the introduction, weak strategies to carry out successful innovations, different ways to involve customers in the product development have been experienced. More brilliant results have been indeed obtained through the involvement of potential buyers in the early stages of NPD cycles [28]. These development policies require a global evaluation of the innovations proposed by companies, rather than judgements about which product features to be primarily enhanced. It is claimed that virtual interaction allows an even more beneficial customer involvement for the discovery of unrevealed needs [29,30]. Nevertheless, also in these cases, the firm is in charge of proactively proposing an initial product idea, to be further refined or even subjected to relevant modifications.

The above examples show how the identification of hidden customer needs and the anticipation of their future expectations represent a key element for the proposal of innovative profiles of products and services. In management sciences this is currently a hot topic within the general debate about business model innovation. A goal shared by several scholars is the identification of patterns of value creation, by exploiting business opportunities [31]. Francis and Bessant [32] address the objective of business model innovation in the "reframing of the current product/service", thus allowing to individuate "new challenges and opportunities". In order to fulfil the task, Johnson et al. [33] depict Customer Value Proposition as the first step in the creation of an alternative business model with the aim of fulfilling unsatisfied needs.

On the path carved out by the studies concerning business model innovation, the already mentioned Blue Ocean Strategy (BOS) combines and presents in a new form several of the most acknowledged concepts of the field: proposition of unprecedented value, redefinition of market boundaries, transition from current industrial standards, etc. BOS has gained consensus in the recent years about its expected capabilities to foster industrial policies aimed at answering unexpressed customer demands by reorganizing market boundaries [34] and overcoming the trade-off between differentiation and low cost [35]. However, even accepting with a pragmatic approach the utility of BOS as a reference source of inspiration, the limited opportunities for the implementation of its clues into the product development cycle are consistently caused by its limited formalism [36]. As a matter of fact, the strategy developed by Kim and Mauborgne results to be very elegant to describe past successes, but it is not really prescriptive [37]. Moreover, the BOS reference tool, i.e. the strategy canvas, stands just for a visual technique to represent ideas that have been separately developed [38].

Hence, also the illustrated managerial approach, although stimulating, is far from achieving the objective of systematically individuating the undeclared customer needs to be addressed [39] due also to a fairly consistent fuzziness. On the contrary, the theoretical framework about business models seems to stand on solid foundations and the phases of NPD following the definition of preliminary ideas result well-supported, also due to the individuation of the right role assigned to customers in the early design stages. On these bases, the necessity holds a paramount importance to overcome the limitations in terms of targeting at the new product characteristics to be fulfilled. As a result, the engineering design community is urged to subsume, elaborate and put in practice the general principles of business model innovation (and more specifically of BOS, that includes the largest collection of tools in this field), as a support for the strategic definition of product platforms [40,41].

2.3. Customer-oriented tools to support decision making within NPD

The traditional models to diagnose the expected sales and profitability results of products lay on the projections of historical data about demands for goods and services. The study endeavours in this field deal with the attempt of minimizing the subjective considerations to be employed within forecasting methods. For instance, recent developments in such thread of research have been presented in [42], whereas a procedure is illustrated to foresee the sales of new products, by improving through simulation tools the predicting capabilities of the models based on sales data.

Techniques which employ data about sales are not applicable to products characterized by novel profiles of attributes, for which few relevant and reliable information is available.

An alternative approach with respect to the demand-driven anticipation of market penetration concerns forecasting or decision support instruments evaluating the expectations of products success by considering the sphere of customer requirements and preferences. This roundabout strategy has witnessed a growing attention in the last decade. A considerable amount of these tools is aimed at supporting the innovation initiatives, by providing guidelines for the development process or directing the choice among multiple product options. Some relevant examples are listed in the followings:

- by considering parameters pertaining to both the industry and the clientele, Sohn and Moon [43] fine-tune an equation to compute the success likelihood of technologies developed by research teams. The model swivels on the American customer satisfaction Index, to which the forecasted success rate of the technology is linked in the manuscript;
- Büyüközkan and Feyzioğlu [44] propose a method employing Artificial Intelligence techniques to select the most favourable product ideas to be developed. The presented approach aims at choosing NPD directions that minimize the presence of uncertainties along the decision making process. The decision system is built upon previous experiences of the involved firms

in terms of established evaluation criteria collected by the marketing team, which include customer needs and satisfaction;
- the knowledge about customers obtained by data mining techniques and, more specifically, their wants and expectations, represent the core of the model developed by Liao et al. [45] to boost competitiveness by guiding towards valuable solutions for both the NPD and the marketing stages;
- Lee et al. [46] entrust a scenario analysis of competing technologies and product platforms to select the product concepts viable to deliver the highest level of customer perceived value, according to metrics pertaining the fulfilled requirements;
- the decision support system described in [47] is based on insights about customers' behaviour and perceived value along the product lifecycle. Their model aims at overcoming the limitations of previous tools for decision-making in NPD, by taking into account formerly disregarded aspects, such as customer satisfaction.
- Orbach and Fruchter [48] have developed a forecasting technique, which takes into consideration the technological and market dimensions to anticipate the evolution and the adoption of product generations. One of the major forces that is accounted in their model concerns the enhancement of certain product attributes that results in consequent modifications of customers' behaviour and willingness to buy.

The mentioned literature sources show a modest degree of mutual interrelationship and a considerable abundance of open issues and intentions for future developments. This allows to claim that the research is progressing and it is surely not exhaustive about the means to facilitate the choices inherent to NPD on the basis of yardsticks pertaining the customer sphere. Moreover, a relevant lack of the described decision support systems is the diffused disregard of the dynamic nature of customer demand (as recalled in Section 2.1), which represents a crucial factor affecting the success of NPD tasks. Chong and Chen [49] review previous contributions and focus on the fragmentary and dispersive research devoted to the variability of customer requirements, as well as to its effects on products success. By dealing with the uncertainty concerning the key characteristics to be fulfilled by the new products, the tools supporting decision-making among different alternatives should therefore account of the dynamic dimension of customer needs.

2.4. Objective of the research

The literature analysis has highlighted the need of developing systematic means capable to aid the crucial decisions occurring in the fuzzy front end of product development. The survey of the available approaches reveals three main deficiencies to be addressed for improving the efficiency of product planning activities:

- lack of reliable methodologies viable to support the identification of the real aspects of value which belong to the latent consumers' and stakeholders' needs; in other terms, the recognition of those latent expectations the customers are ready to pay for is still mostly related to entrepreneurs' and designers' intuition, rather than on a proper systematic approach;
- scarce availability of general models having the capability to represent the dynamic evolution of customer needs; the most meaningful methodological efforts in the field of product development have been dedicated to the reduction of the lead time, being it the most effective way to prevent the delivery of obsolete products since their first launch on the market; besides, a reliable model on the evolution of customer needs and their relative urgency could dramatically reduce the risk of market failures, especially in rapidly evolving market sectors;
- absence of objective and reliable models by which to predict the market appraisal of a novel product idea in a given industry; in this context, a plenty of systems that employ judgements of consumers are indeed deemed untrustworthy.

Among the open research issues underlying the identified methodological lacks, this paper focuses on the third target. The assumption behind this choice is that the availability of reliable metrics to estimate the expected market appraisal of an innovative product or service will also constitute a significant support for the development of methods and tools dedicated to the previous issues.

In turn, the target assessment metrics should be characterized by the following features:

- high flexibility to allow the estimation of market expected appraisal both with innovative products and services regardless their industrial domain;
- applicability since the earliest stages of product planning, when the physical characteristics of the product are still extremely fuzzy, relying only on the target product specification, i.e. its attributes profile;
- no need to conduct customers surveys, or to directly involve any stakeholder in the innovation process;
- easy to learn and to apply in any industrial context so to avoid major obstacles to its introduction in professional environments.

3. Exploring metrics to estimate the expected perceived value of an innovative product profile

This section presents the research outcomes about the definition of a metric capable to quantitatively assess the probability of success related to one or more new product development initiatives, characterized by the features depicted in the previous paragraph. This exploratory work aims at determining the chances of success by evaluating the value profile of an innovative product with respect to the commercial outcomes displayed by a set of analogous known experiences.

The construction of the value assessment metrics has been accomplished through the following activities:

1. Identification of suitable clustering criteria allowing the classification of the product features according to:
   a. the functional role they play for stakeholders' satisfaction and potential dissatisfaction;
   b. the occurred value profile transformations which have given rise to radical product differentiation with respect to established standards in the reference industry.
2. Selection of the case studies constituting the reference sample on which the system grounds the assessment. They concern successful and unsuccessful stories related to the introduction of radical new products or services in the market, supported by adequate availability of information in scientific and/or technical literature.
3. Analysis of the collected case studies aimed at identifying the value profiles in terms of product features and classification of such parameters according to the criteria defined in the step 1.
4. Correlation of the classified value profiles with the encountered market appraisal and subsequent identification of patterns for the preliminary assessment of the potential success of a new product. Such an activity has been performed by exploring two different approaches based on:
   a. a statistical model obtained through the application of the binary Logistic Regression;

b. an empirical model exploiting artificial Neural Networks.
5. Cross-validation of the obtained models aimed at verifying the over-fitting degree and subsequent evaluation of the intrinsic forecasting capabilities.

The following sections describe in details all the above-mentioned activities in addition to the ensuing outcomes.

3.1. Categories to describe the phenomena underpinning value transitions

The twofold objective of characterizing the patterns of change and describing aspects related to the fulfilment of customer needs has been pursued by introducing a two-dimensional space to categorize the drivers of value-wise innovation initiatives.

On the one hand, the description of NVP experiences includes the Four Actions Framework (FAF), which depicts the occurred transformations to which features and product attributes are subjected, with respect to the profile of established standards in the reference industry. On the other hand, the same attributes are classified according to a functional logic, which depicts the way such characteristics contribute to provide satisfaction or potential dissatisfaction for the buyer, the user or any other stakeholder.

The FAF is a scheme introduced within BOS, viable to summarize the designed decisions undertaken in order to sketch an alternative profile. This classification allows to highlight the typical events (actions) that take place in radical redefinitions of products and services with reference to phenomena regarding the drivers for customer satisfaction. According to the principles of FAF, the attributes showing variations between different generations of a product are alternatively:

- introduced within the bundle of features relevant for the product configuration (action Create);
- subjected to a considerable increase of their performance (action Raise), with the consequent incremented capability to impact on customer value;
- subjected to a remarkable diminishment of their offering level (action Reduce), determining a minor entrustment on their capability to excite the interest of customers;

Table 1
Functional features to classify product attributes subjected to BOS actions within value transitions.

Functional features	Illustrative examples
Useful functions (UF): positive outcomes delivered by the system to the buyer, the user or the beneficiary	◦ The advantages arising from the exploitation of the product, which can be referred to the quality and the quantity of the desired output; ◦ the amount of users for whom such benefits are met, thus the flexibility of the product according to different customer demands; ◦ the capability of the product to meet the customer needs within the requested time; ◦ the adaptability of the product when working in diverging conditions with respect to the designed preferred ones; ◦ the stability of the product performances when subjected to external perturbations; ◦ the chance to effectively control the system in order to obtain the expected outcomes; ◦ the possibility to expand or upgrade the range of product functioning; ◦ the opportunity provided to advantageously employ the product for not standard users or disabled people; ◦ the possibility to customize the product or certain properties according to the user tastes and tendencies; ◦ the possibility to use the system for different employments after the termination of main product functioning; ◦ the aesthetical requirements and the emotional dimension of the product, the style, the fashion content, what it evokes in the user, the lifestyle that the object implies, the prestige it generates for the owner as a feeling of distinction and recognition; ◦ the fun and adventure resulting from the use of the system.
Harmful functions (HF): measures to attenuate drawbacks provoked by the system	◦ The integrity of the product itself, its resistance to planned or accidental stress or collisions, the strength against wear or corrosion; ◦ the limitation of damages towards treated objects or neighbouring systems; ◦ the environmental sustainability, the recyclability, the possibility to reuse the system or its parts reducing the amount of waste; ◦ the ethics of the product as a distinguishing factor; ◦ the safety and innocuousness for human health and people's psychological and social conditions; ◦ the absence of bother for the user employing the product or for surrounding people, the comfort of use, the ergonomics, the manageability; ◦ the reliability, the limited frequency of system failures; ◦ the duration, the expected life of the product.
Resources (RES): mitigation of the impact due to the consumption of the resources in charge of customers, users or any stakeholder	◦ The limitation of occupied space, the lessening of the encumbrance, the accessibility, meant as a shrunk quantity of space required to allow the users to employ, store, transport, maintain and dismantle the product; ◦ the working speed, the reduction of time to be waited before the functioning of the product delivers the expected outcomes, including the duration of the period to be waited before physically benefiting of the bought item or service after the purchase; ◦ the limitation of the time required to maintain or fix the product, to change accessories, to dismantle the system, to learn how to use it, to administer or to accomplish the involved bureaucracies; ◦ the reduction of the information and skills to be gathered in order to correctly use and control the product, the ease of employment, the user friendliness, the limitation of required training; ◦ the ease of acquiring the product, due to market penetration and distribution policies; ◦ the ease of managing, maintaining, assembling, disassembling, upgrading, substituting components or accessories; ◦ the ease of choosing and individuating the product in the marketplace, according to recognizable features, due to technical, aesthetical or communication issues; ◦ the independence from the use of different materials, instruments, technical systems; ◦ the absence or limitation of the consumption of consumable items or materials; ◦ the reduction of auxiliary functions to be delivered in order to use, install, dismount or dispose the system; ◦ the limitation of the required energy needed for the product working, maintaining, installing, disposing, recycling; its efficiency; ◦ the decrease of the human power needed to use or transport the product, including its lightness and portability; ◦ the additional services provided in order to attenuate the consumption of individual resources, as those listed in the previous bullets, the customer care.

- removed from the set of relevant competing factors (action Eliminate).

For the sake of clarity, unaltered performances and slight modifications of offering levels for any attribute are not considered relevant for the purpose of designing new products or services.

Therefore, the modifications of the product or service features that led to the new value profile are assessed with respect to the following aspects, which relate to the four actions in the same order they have been presented above:

- which unprecedented sources of value for customers have been introduced;
- which characteristics have undergone an increment of the performance well above the current industry standard;
- which features have experienced a drastic reduction of their performance;
- which characteristics have been eliminated in the value transition.

Along the categorization of the phenomena that participate in a value-oriented development of products and services, the second dimension refers to the diverse ways the customer requirements affect the fulfilment of needs. With such an objective, the previously identified features, hence those subjected to any value-transition action, can be clustered according to the functional role they play within customer perception of product and services from the viewpoint of the user or any stakeholder. By employing the classical dimensions that characterize the efficiency of technical systems in Value Engineering [50], the attributes would be classified just in terms of expected functionality and cost aspects. Through the evolution of the seeded concept of value in the engineering domain, the TRIZ community proposes a more comprehensive evaluation characterized by three terms to estimate the distance of a given system from "ideality", as explicated, e.g. in [51].

By adopting the terms used in TRIZ, the clusters for classifying product/service attributes stand in:

- features related to the delivery of useful functions (UF attributes), meant as the direct benefits perceived by the recipients for whom the product or service has been designed;
- characteristics aimed at eliminating or attenuating the undesired side effects (HF attributes), commonly associated with the product;
- properties leading to the reduction of the resources consumption from the viewpoint of any stakeholder (RES attributes) and capable to influence the adoption of a new product/service [20] (see also Section 2.1).

The adopted functional classification scheme is summarized in Table 1, supplemented by suitable illustrative examples. The reported list, although not exhaustive, owns the capability of abstractly describing a wide set of attributes by covering, e.g. the whole sample of product/service characteristics (roughly 750, as inferable from Table 4) subjected to change in the 92 value innovations reported in Section 3.2. Furthermore, the set of examples of UF, HF and RES functional features collected in the table has been proficiently exploited for innovation purposes in industrial contexts [52].

As a result, the characterization of any new value profile is carried out by counting how many attributes described throughout the same functional feature are subjected to the same action. The crossed interrelationships among actions (4 types) and functional features (3 kinds) give rise to the definition of 12 categories to represent the changes between different product profiles. The so defined categories, on the basis of the provided description of both the actions and the functional features, contribute to consistently reduce the subjectivity of the forecasting process, since they require just a minor human involvement in discerning the differentiation factors with respect to previous generations of products.

3.2. Selection of the case studies

The collection of case studies about radical value transitions has resulted in a comprehensive set of successful stories and market failures, as claimed by a plurality of scientific and/or technical literature sources. Additionally, in order to be included in the sample of the reference case studies, the transformations of the value profiles with respect to previous standards had to be attested in more than one document, without any conflicting indication and involving at least three attributes subjected to noticeable modifications.

The final sample consists of 92 case studies, equally distributed among success stories and market flops. The latter subset includes items rejected by consumers due to disregarded value aspects, as well as products with a marginal market penetration if compared with the expectations of the firm and/or the massive advertising investments. It is worth noting that due to the general lack of documentation about unsuccessful experiences, market failures are so far insufficiently explored for supporting decision making in NPD activities, as claimed in [53]. The subset of success stories includes, beyond marketed items showing remarkable commercial results, cases of shattering innovations with a high social influence, new generations of products and services, systems with new dimensions of value for customers or stakeholders.

The 92 case studies related to the proposition of innovative value profiles obtained by a search conducted within journal articles, books, web sites and forums, are listed in Table 2.

Table 2
Selected case studies related to the proposition of innovative value profiles.

Success stories	[Yellow Tail] wines, Apple IPod, Barnes & Noble booksellers, Bert Claeys Kinepolis, Bloomberg, Body Shop cosmetics, Bratton's New York Transit Police, Callaway Golf "Big Bertha", Canon copiers, Cirque du Soleil, CNN, Compaq in Server Industry (1992–1994), Croc's, Curves fitness company, Direct Line, EFS – Corporate Foreign Exchange, Facebook, Ford Model T, Formule 1, Geox, Herman Miller Aeron Chair, Home Depot, Hubspot, IKEA, Intuit Quicken™, iTunes, JCDecaux, Joint Strike FighterF-35, NetJets, Nintendo WII, Novo Nordisk Novopen®, Outlet Villages, Pfizer Viagra, Philips Alto bulb, Pink Taxi, Polo Ralph Lauren, QB House barbershops, RedBull, RIM's Blackberry, SAP R/2, Sony Walkman, Southwest Airlines, Swatch, Toyota Prius, Virgin Atlantic, Youtube
Market failures	Amphicar, Apple Lisa, Apple Newton, BMW C1 motorbike, Cadillac Cimarron, Campbell's Souper Combo, CueCat, Dell's Web PC, Digital Audio Tape, Dive Restaurant, Dreamcast, DuPont's Corfam, Earring Magic Ken, Evilla Sony, Federal Express' Zap Mail, Ford Edsel, Gerber Singles, IBM PC jr, Kellogg's Cereal Mates, La Femme, Lynx barber shop, Maxwell House ready-to-drink coffee, McDonalds' Arch Deluxe, Microsoft BOB, Motorola Iridium, New Coke, Nintendo Virtual Boy, Nokia N-Gage, OK Soda, OS/2, Pepsi AM, Pepsi Crystal, Philips CD-I, Planet Hollywood, Polaroid Polavision, Quadraphonic Sound, Rasna Limited's Oranjolt, RJ Reynolds Premier smokeless cigarettes, Sony Betamax, Sony Minidisc, Sony's Godzilla, Telecom Italia FIDO – Digital Enhanced Cordless Telecommunications, The Hot Wheels and Barbie computer, Thirsty Cat! and Thirsty Dog!, Unilever Persil Power, Voice Pod

Table 3
Excerpt of the matrix reporting the classification of attributes related to the 92 case studies analysed to build the value assessment metric.

Case study	Create UF	Create HF	Create RES	Raise UF	Raise HF	Raise RES	Reduce UF	Reduce HF	Reduce RES	Eliminate UF	Eliminate HF	Eliminate RES	Success?
[Yellow tail] Wines	1	0	1	1	0	1	2	0	1	2	0	0	1
Amphicar	2	0	0	0	0	0	3	1	3	0	1	0	0
							(...)						
Youtube	2	0	2	0	0	1	0	3	0	0	0	0	1

Reflections about all the gathered case studies have been then conducted with the aim of identifying the main attributes characterizing the offered value profiles, the needs which were meant to be satisfied, the trade-offs among not compatible demands. The identified features have allowed the characterization of each NVP story according to the above-defined categories. In order to carry out this task, the data collected about each innovation have been carefully and independently analysed by two researchers and then openly discussed among the four authors in order to check incongruent evaluations and to limit the subjectivity of the following classifications.

As a result of the analysis each case study has been represented through a vector including 13 cells:

- 3 cells with the number of attributes subjected to the "create" action and classified, respectively, with UF, HF and RES;
- 9 further analogous cells, with respect to the related functional features, expressing the amount of attributes subjected to the three remaining FAF actions (raise, reduce, eliminate);
- a binary cell discerning whether the case study is reported as a successful innovation (assuming value 1) or as a market failure (represented by the value 0).

Table 3 depicts an excerpt of the resulting 92 × 13 matrix.

Eventually, with a distinction between the two main classes of case studies, Table 4 summarizes the global number of value attributes distributed according to the classification into functional features and with reference to the actions they undergo.

3.3. Value Assessment Metrics

The survey of documented case studies represents the basis for the determination of metrics to estimate the potential success of NVP initiatives, then, to help tackling decisions about future investments. In this sense, it is required to employ mathematical or empirical models capable to relate multiple inputs with an output, representing the chances of thriving in the marketplace.

The literature is populated by numerous model-building techniques, based on statistical science and achieved through artificial intelligence. Many of them have been developed for fitting the exigencies of different disciplines; however, to the scope of this work, the authors have opted for the employment of prediction models which are acknowledged by vast arenas.

According to the objectives, a pair of approaches has been experimented in order to reveal the most promising (if any) pattern for forecasting the success of NVPs, i.e. a statistical tool (namely the binary Logistic Regression) and the artificial Neural Networks. More in detail, the Logistic Regression was employed as an acknowledged technique rooted in statistical sciences for multivariate analysis. On the other hand, artificial Neural Networks represent diffused computation models inspired by biological systems, which can be assumed as "black-boxes", thus capable of relating inputs and outputs without explaining (ex-post) possible relationships between them.

Such approaches are largely considered valuable techniques to support decision making through quantitative models [54], as well the most established and diffused instruments for predicting purposes [55]. According to the last cited survey [55], the Neural Networks typically outperform statistical tools in approximating any non-linear mathematical function, but they cannot explain meaning and significance of the input variables.

This work intends to check the applicability of these alternative modelling techniques to innovation value assessment; both the approaches are characterized by strengths and shortcomings, which might lead to erroneous evaluations and consequently to wrong decisions. More insights are reported in the final discussions about the operability of both the proposed models within the present field of research.

3.3.1. Value Assessment Metrics through binary Logistic Regression

The binary Logistic Regression, widely documented in the statistics literature (e.g. in [56]), was adopted given its capability to model the dependence of a binary response variable (success or failure, in the present case), as a function of more explanatory variables [57]. Furthermore, with respect to other regression models, it provides success percentages ranging from 0 to 100%, thus within the pertinent interval. Its employment is widely witnessed in the literature as a means to anticipate the success of new products on the basis of a multivariate analysis [58,59].

Aiming at building the Logistic Regression model for the present research, the choice was made to use half of the available success and failures case studies, which were randomly selected. The residuals were hence employed to verify the predicting capabilities of the model. The regression was carried out through the Minitab® v.16, which makes use of the maximum likelihood estimation criterion. The task gave rise to the following formulation of the parameter:

$$z = -3.19 + 3.44 \times \text{UF/create} + 1.32 \times \text{HF/create} + 2.87 \times \text{RES/create} + 0.97 \times \text{UF/raise} + 1.75 \times \text{HF/raise} + 0.41 \times \text{RES/raise} - 0.84 \times \text{UF/reduce} - 0.27 \times \text{HF/reduce} - 1.78 \times \text{RES/reduce} - 0.46 \times \text{UF/eliminate} - 9.49 \times \text{HF/eliminate} - 1.65 \times \text{RES/eliminate}, \quad (1)$$

Table 4
First level classification of the value attributes of the 92 case studies mentioned in Section 3.1.

	UF	HF	RES	Tot
Success stories				
Create	66	12	32	110
Raise	59	20	68	147
Reduce	53	13	21	87
Eliminate	43	3	15	61
Tot	221	48	136	405
Market failures				
Create	37	8	12	57
Raise	6	8	43	107
Reduce	66	12	54	132
Eliminate	30	9	16	55
Tot	189	37	125	351

that allows to calculate the Value Assessment Metric (VAM) throughout the Logistic Regression as the extent of success likelihood:

$$\text{VAM (reg)} = \frac{1}{1+e^{-z}} \tag{2}$$

The software employed to carry out the regression supplies relevant indications about the reliability of the results. The hypothesis assessing that all coefficients are 0, as proposed in the Log-Likelihood test, can be rejected with a great confidence (the reported p-value is 0 until the third decimal place). Such results provide evidence about the statistical significance of the input variables (i.e. the number of actions per functional feature) in explaining the success or the failure of NVP initiatives.

Furthermore, the outcomes of additional tests are offered in order to discuss the goodness of fit of the regression. In order to measure the accuracy of the model with respect to the introduced data, the p-values are extracted with reference to three different tests, i.e. Pearson, deviance and Hosmer–Lemeshow. The last one [60] is commonly devoted to evaluate the goodness of fit of models including any quantity of explanatory variables [57]. Since the obtained p-values range from 0.609 to 0.997, there is insufficient evidence to claim that the model does not fit the data adequately.

As a result of the previously discussed issues, the proposed explanatory variables are meaningful to motivate the success of value-wise NPD programmes and the regression model can be considered satisfactorily correct and robust.

3.3.2. Value Assessment Metrics through artificial Neural Network

Thanks to the "learning" power about the relationships between inputs and outputs, Neural Networks (NNs), especially in their feed-forward fashion, are assumed as universal "approximators" and have become well-established tools for forecasting purposes. Paliwal and Kumar [55], by reviewing successful applications of NN models, highlight how this has regarded various fields, including accounting and finance, health and medicine, engineering, manufacturing and marketing. Among the others, Wang and Chien [61] presented a NN-based forecasting model that predicts innovation performances on the basis of corporate objectives and technical resources. Thieme et al. [62] developed a NN decision support system linking NPD decisions to a dichotomous success/failure variable.

In order to develop a preliminary model viable to indicate a possible market response to a modification of the product profile, a feed-forward NN has been implemented. The MATLAB Neural Network Toolbox was the tool adopted to create, train, validate and simulate the network.

The process of building a NN has to take into account input and target variables, activation functions, network structure and training algorithm. While the values of the 12 categories recorded in each of the 92 analysed cases (Table 3) have been used as the input of the system, a binary function distinguishing between successful innovations and market failures has been adopted as target, as in [62].

In order to obtain outputs approaching symmetrically to the extremes of the target interval, the sigmoid activation function (3) has been adopted for the input and the output layers. However this has required a slight modification with respect to the data available in Table 3, assigning the value −1 for the failure cases. A transformation function will be employed in the followings to obtain quantities expressing probability of success within the expected range.

$$f(x) = \frac{(e^{x} - e^{-x})}{(e^{x} + e^{-x})} \tag{3}$$

As mentioned above, the definition of the structure is one of the main issues concerning the implementation of the NN, choosing at first to adopt one or more hidden layers linking input and output variables. Each layer is to be designed, being composed of processing units named hidden nodes. The layers are connected by weighted links.

According to Russell and Norvig [63], the quantity of hidden layers and hidden nodes represent the most crucial factor to be deliberated for a feed-forward NN. In this sense, many techniques have been proposed in order to support the definition of NN architectures [64]. Tamura and Tateishi [65] have compared a three and a four layered feed-forward NN, with $(N-1)$ and $[(N/2)+3]$ hidden nodes respectively. While the former can exactly describe any N input-target relationship, the latter is capable to describe the same function with an arbitrary small error and outperforms the previous one in terms of the aspects related to the training of the network.

In order to compare the efficiency of different learning algorithms and to avoid over-fitting (i.e. the phenomenon according to which the NN loses its ability to predict data sets not used for the training), two alternatives have been tested. In detail, the Gradient Descent Learning Algorithm (GDLA) and Levenberg–Marquardt Back-Propagation (LMBP) algorithm have been employed before making the definitive choice about the training algorithm.

The input matrix constituted by the case studies has been randomly subdivided into three subsets for training (60% of the sample), validating (20%) and testing (20%) the NN, according to the default proportions adopted by the MATLAB Neural Network Toolbox.

Several NN topologies have been tested, using heuristic rules to supervise the suitable training network. The results have been at first evaluated in terms of:

- the Mean Squared Error (MSE), measuring the difference between the actual target and the value predicted by the model, with regards to the examples belonging to the validation subset;
- the correlation coefficient R, a statistical measure of the strength of the relationship between the actual versus predicted outputs. The R coefficient can range from +1 to −1. The closer is R to 1, the stronger is the positive linear relationship, and vice versa;
- the correspondence between the emerging outputs and the real target, with reference to the validating and testing subsets.

The correspondence degree has been evaluated as follows. The output of the NN, if scaled up to a [0,1] interval, through the expression (4), can be considered as a measure of market success possibilities of a given attribute profile:

$$\text{VAM (NN)} = \frac{y+1}{2} \tag{4}$$

The compliance between the outputs provided by the NN and the observed success of the NVPs can be evaluated by simulating the 36 case studies not used for training the network. The error is calculated as the difference between the output generated by the NN and the target provided by the user. The assumption is that a value of VAM (NN) greater than 0.5 points at success stories, while VAM (NN) values lower than 0.5 are representative of market failures. The residuals have to be considered, of course, not compliant with the present cross-validation test.

The best results have been obtained with a four-layered network, shown in Fig. 1, with 7 and 2 hidden units in the first and second hidden layers respectively.

With reference to the previously listed criteria to evaluate the NN, a comparison between the efficiency GDLA and LMBP is shown in Table 5.

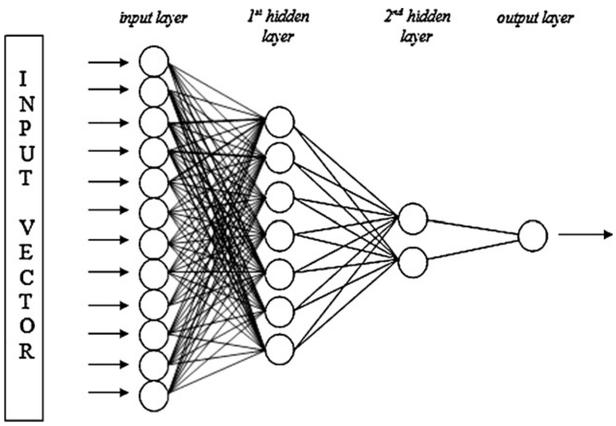

Fig. 1. Network architecture.

On the basis of the results reported in Table 5, despite the LMBPA has shown a higher overall correlation between outputs and targets, the NN with GDLA has proved better performance with data not used for the training and a lower MSE. The simulation by means of the NN trained through the GDLA has returned 4 cases of incongruence with the target, giving rise to a global correspondence percentage equal to 88.9%.

3.4. Cross-validation of the Value Assessment Metrics

The employment of the cross-validation technique is well acknowledged in the literature as a means to check the reliability of empirical models. The cross-validation of the VAM (reg) and the VAM (NN) is herein presented and the results are compared in terms of their predictive capabilities.

With reference to the regression model, it is first necessary to substitute the number of each involved action per functional feature, according to the matching explanatory variables in (1). The resulting coefficient z has then to be substituted in the expression (2), so to obtain the expected success rate. The computing procedure is applied to the NVP cases not employed to perform the regression, which contributes to verify the robustness of the model [66] through the cross-validation technique. The results have been considered satisfactory for success stories showing a VAM (reg) index greater than 50% (true positives) or, mutatis mutandis, for market failures associated with a rate of success likelihood lower than that extent (true negatives). In the other circumstances the application of the model has to be considered erroneous (false positives for observed market failures and false negatives for not diagnosed successes). The analysis highlights a positive match between the value of VAM (reg) and the effective success of the new proposed profile in 37 cases out of the 46 not included in the construction of the model (23 success stories and 23 market failures). More in detail, the observed mistakes regard 5 false positives (Apple Lisa, Dive Restaurant, Dreamcast, Planet Hollywood, Telecom Italia FIDO), showing VAM (reg) indexes ranging from 57.0 to 99.9%, and 4 false negatives (Callaway Golf "Big Bertha", Facebook, Formule 1 and Geox), whereas the expected computed success is included in the interval 0.0–38.5%.

With respect to the 36 cases not used for the training phase of the NN model (21 market flops and 15 successes, as randomly picked up by the employed software), 4 of them did not match with the expected range of VAM (NN) values, as reported in Section 3.3.2. More specifically the mistakes refer to 2 false positives (Dive Restaurant and Telecom Italia FIDO), with VAM (reg) indexes equal to 76.7 and 81.5% and to an analogous quantity of false negatives, i.e. JCDecaux and Geox, whose computed probability of success is 2.0% and 46.8%, respectively.

The outcomes of the test are summarized in Table 6.

The emerging results allow to calculate the values pertaining the precision (ratio between the number of true and totally displayed positives) and the recall (ratio between the number of emerging true and real positives) for the cross-validation, which results as a common measure to highlight the capabilities of statistical models, such as logistic regression experiments [67,68] and Neural Networks [69,70]. The recalled quantities, originally belonging to the information retrieval field and standing for the relevance of the results, can be combined in order to obtain more complex indexes to express the predicting capabilities, inherent to Logistic Regression models, such as *F*-measure [70,71] and Matthews correlation coefficient [72,73].

Within the context of the present research, such indexes represent:

- Precision: reliability about the individuated successes;
- Recall: capability of revealing potential successes;
- *F*-measure: accuracy of the test, as a balanced measure between the previous items;
- Matthews correlation coefficient: balanced performance of the test, which includes also the capability to discern the unsuccessful projects.

A general evaluation of the outcomes can be performed by comparing the results with other experiences. A reference model to be compared against has been individuated in the decision support system, named EBONSAI [74], given the similarity of its objectives, i.e. the anticipation of market success of products. EBONSAI has not been mentioned in Section 2.2 since its assessment relies on time-series purchase transaction data and not on consumers' needs categorization; however, it constitutes a relevant benchmark to support the thesis of this paper.

Table 5
Comparison of the two algorithm learning methods.

	Levenberg–Marquardt Back-Propagation Algorithm	Gradient descent learning algorithm
MSE	0.441	0.348
R – whole sample	0.859	0.733
R – validation subset	0.628	0.802
R – test subset	0.618	0.720
% Correspondence	83.8%	88.9%

Table 6
Results of the cross-validation test.

Kind of result of the test	Logistic regression	Neural network
True negative	18	19
True positive	19	13
False positive	5	2
False negative	4	2

Table 7
Compared results about the predicting capabilities of models to anticipate the market success and penetration of new products.

Index	VAM (reg)	VAM (NN)	EBONSAI
Precision	0.79	0.87	0.62
Recall	0.83	0.87	0.87
F-measure	0.81	0.87	0.72
Matthews correlation coefficient	0.61	0.77	0.26

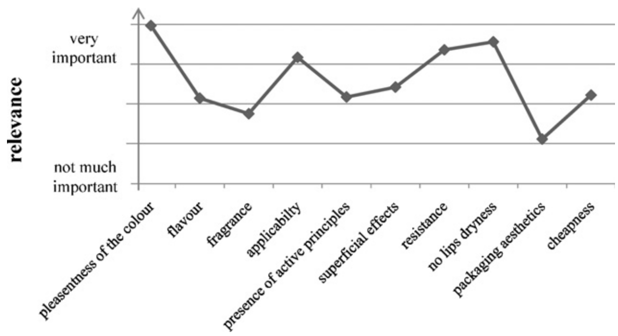

Fig. 2. Graphic representation of lipstick attributes importance perceived by the users.

The results summarized in Table 7 show the excellent capabilities of the *VAM* indexes, which outperform the models reported in the literature.

4. Verification of the Value Assessment Metrics

In order to show the usability of the proposed VAMs and to preliminarily check their consistency, the authors have firstly organized a laboratory test regarding the cosmetics industry, by designing three new value profiles of a make-up lipstick. Said activity is described in detail in Section 4.1. The encouraging results obtained with the first test have suggested the extension of the VAM test to an industrial case study concerning the development of an innovative concealed hinge, as reported in Section 4.2

4.1. Exemplary application of the VAMs: value assessment of innovative lipsticks

A lipstick is typically composed of a cylindrical stick used for the lips colouring inserted into a primary packaging useful for the stick conservation. The function of the item consists in applying colour and texture to the lips. Starting from an industrial investigation about the value generating attributes for the considered product [75], the authors have identified twenty-three customers requirements that companies have long competed on.

The attributes have been rated in terms of the importance perceived by the user, by means of a survey among a sample of 36 women aged between 20 and 35 years old. Fig. 2 depicts a subset of the results of the survey pertaining ten customer requirements relevant for the purpose of the explanation of the test. Subsequently, a market research has been conducted in order to evaluate the performances of a large sample of existing lipsticks, in terms of the quality level of the offering concerning said attributes. The mean values detected in each analysed product has brought to the definition of the value curve of a standard lipstick, which includes the same ten attributes, as shown in Fig. 3.

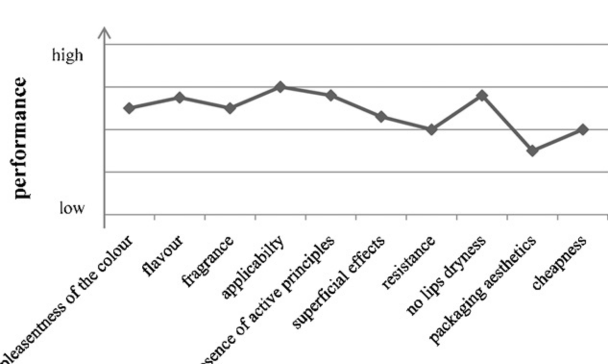

Fig. 3. Value curve of a standard lipstick.

Table 8
New value propositions applied to a lipstick and related estimation of the market potential through the VAMs.

Lipstick 1 – VAM (reg) = 97.4%; VAM (NN) = 62.9% Expected success	
Create UF (brand image)	Raise UF (niceness of fragrance)
Raise UF (packaging design)	Raise HF (absence of dryness)
Raise UF (range of colours)	Reduce RES (cheapness)
Raise UF (pleasantness of flavour)	Eliminate UF (innovative active principles)
Description: the primary packaging of the lipstick resembles Pop Art design objects (e.g. Campbell's Tomato Soup) and can be collected when the product is finished. Range of colours and fragrance are increased, while the cost is higher than standard products and there are no special active principles to give it better properties (e.g. in terms of moistening the lips)	
Lipstick 2 – VAM (reg) = 86.2%; VAM (NN) = 73.0% Expected success	
Create UF (colours of customizable lipstick)	Reduce UF (lipstick maintaining)
Raise UF (range of colours)	Reduce RES (cheapness)
Raise HF (absence of dryness)	Eliminate UF (pleasantness of flavour)
Raise UF (applicability)	Raise UF (niceness of fragrance)
Description: the product is constituted by a dispenser with mixes three components to produce a variable colour lipstick. The product is rechargeable by acquiring the basic colours to be mixed. Besides, the product has no special fragrance or flavour. The cost of the dispenser is about the double of a standard lipstick and each refill costs as a standard product.	
Lipstick 3 – VAM (reg) = 15.1%; VAM (NN) = 3.8% Expected failure	
Create RES (lipstick quantity)	Reduce HF (absence of dryness)
Create HF (absence of deterioration)	Reduce RES (cheapness)
Raise UF (lipstick maintaining)	Eliminate RES (compactness of packaging)
Description: while a standard lipstick is supposed to last for 300 applications, it is proposed a product, bigger than a usual one (25 g instead of 16 g), capable to deliver 500 applications. The lipstick is characterized by average moistening properties and high duration of each application. The overall cost is slightly higher than usual, but the unitary cost per application is lower.	

Starting from the value profile of the benchmark lipstick reported in Fig. 3, the authors have designed three innovative product configurations. With regards to the general idea of the FAF, the task has been performed by introducing new attributes, suppressing competing factors and shifting the values of some performances with respect to those of the market standard.

The resulting profiles take into consideration at different degrees the VoC, as expressed through the accounted importance of each dimension of value and summarized in Fig. 2. For instance, a NVP focuses on the most important attribute, i.e. the colour, by expanding the range of available hues. On the other hand, another profile swivels on a scarcely relevant attribute, according to the users' opinion, namely the packaging aesthetics.

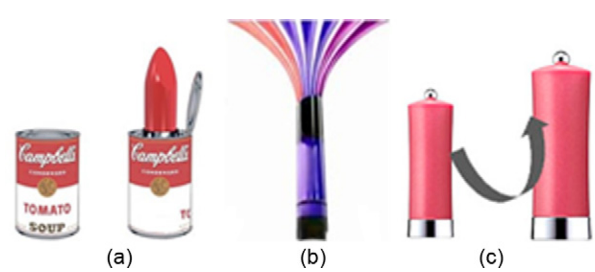

Fig. 4. Sketches of the product concepts resulting by the fist (a), second (b) and third (c) new value proposition for a make-up lipstick.

Table 9
Degree of appraisal for innovative profiles of a lipstick.

	Lipstick 1	Lipstick 2	Lipstick 3	Existing lipstick
Sample 1 (#43)	11	15	6	11
Sample 2 (#58)	12	27	4	15
Total (#101)	23	42	10	26
% Sample 1	25.6%	34.9%	14.0%	25.6%
% Sample 2	20.7%	46.6%	6.9%	25.9%
%Total	22.8%	41.6%	9.9%	25.7%

The NVPs are summarized in Table 8, which includes, beyond the actions of the FAF and the subjected competing factors, the characterization of the attributes through the functional features. The table additionally includes a concise description of the proposed profiles and shows the VAM indexes, according to the metrics resulting by the Logistic Regression and the Neural Networks. For a better understanding of the designed profiles, Fig. 4 provides a sketch of the artefacts responding to the matching value redefinitions.

The actual evaluation of the real probability of success or failure is a complex problem and however out of the scope of this paper; nevertheless, the authors have defined a questionnaire in order to obtain a preliminary degree of appraisal of the innovative profiles; two separate samples of convenience were constituted by:

- 43 female students of the second year of degree course in Fashion Design at Politecnico di Milano, Italy;
- 58 women aged between 20 and 50 years old, coming from different European countries and with very diversified professions and interests.

The respondents were asked to indicate the preferred lipstick profile, choosing just one product among the three alternatives depicted in Table 8 and a fourth option inspired by an existing product from a famous brand (L'Oreal "Color Riche", whose brand name was hidden in the test), well representing the high-end of market offer.

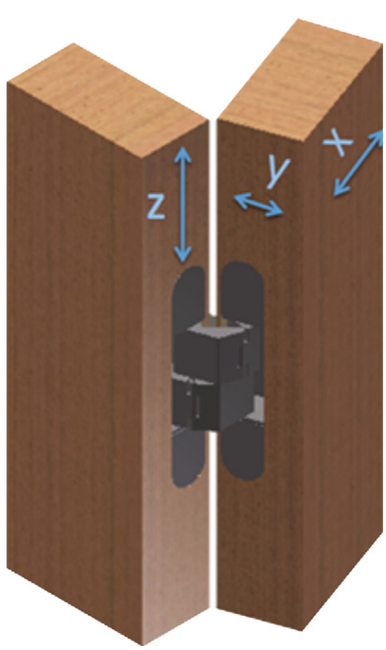

Fig. 5. Sketch of a classical concealed hinge.

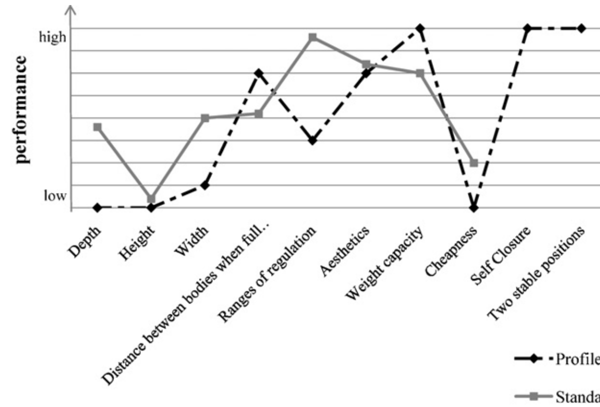

Fig. 6. Comparison between the value curve of the first innovative profile and that of a standard invisible hinge.

The size of the samples employed for the experiment does not represent an exhaustive quantity of observations for the purpose of a full validation test. However, the outcomes of the interviews, illustrated in Table 9, allow to assess that the samples are not independent, as checked through a χ^2 test, and thus that the data are sufficient to carry out preliminary considerations, by depicting a consistent trend.

The results of the questionnaire show that the degree of appraisal of the expectedly successful innovative profiles is widely greater than that of the predicted flop (according to both the VAM metrics). With regards to the present verification experiment, a limitation of the model stands in the nature of the test itself, since declaration of interest and purchasing a product are certainly correlated figures, but not coincident. Moreover, although discerning between attracting value propositions and potential failures, the model has not precisely identified the most promising alternative (the second profile, according to the interviews).

4.2. Industrial application of the VAMs: value assessment of innovative concealed hinges

The VAMs were further employed in an industrial application, in order to evaluate the potential success of two innovative product profiles and select the most promising development strategy. The authors participated to an industrial research project involving OTLAV S.p.A., an Italian firm producing hinges. The aim of the collaboration, lasting six months starting from March 2011, was the development of an innovative concept about concealed hinges.

Similarly to the exemplary lipstick application, the authors first surveyed the main kinds of existing concealed hinges, for which a classical design is reported in Fig. 5. This analysis brought to the identification of the most relevant competing factors and the performance levels of the analysed products, with respect to said attributes. This allowed to draw the value curve of the "standard product", as shown in Fig. 6 (continuous line).

Thus, the authors, together with OTLAV technical staff, identified a list of features capable of differentiating a hypothetical new product with respect to those already existing on the market. The whole sample of both existing and potentially innovative attributes was analysed from the view point of all the stakeholders interacting with an invisible hinge (i.e. interior designers, installers, dealers, final users). However, the attributes functional classification was finally performed from the viewpoint of the final user, because in this application the stakeholders' requirements often fit those of the final users.

Table 10
Four Actions Framework and TRIZ functional classification applied to the definition of a first innovative product profile.

Profile 1: Self-closing concealed hinge	
Create RES (self-closure)	Create UF (two stable positions)
Raise UF (distance between bodies)	Raise HF (weight capacity)
Raise HF (reduced impact on door aesthetics)	Reduce RES (cheapness)
Reduce HF (ranges of regulations)	Eliminate RES (compactness of dimensions)

Subsequently, two novel product concepts were selected from a bundle of potential new profiles resulting through the application of the FAF, according to the supposed quick feasibility of the thought items.

The first chosen profile consisted in a self-closing concealed hinge, capable of standing two stable positions and of raising the distance between the two bodies composing the hinge in a full open position. Such hinge was conceived in order to sustain the functioning of heavy doors and to have a limited impact on the overall aesthetics. With respect to a traditional invisible hinge, the cost of the proposed profile was estimated to be higher, because of the components employed to achieve the automatic closure. Furthermore, the ranges of regulation along the three axes were reduced and the compactness of size, with particular reference to the depth direction (*x*-axis in Fig. 5), should not be considered anymore within the bundle of competing factors.

The value proposition of said profile and the classification of the involved attributes are summarized in Table 10, whereas a comparison between the value curve of the first innovative profile and that of a standard invisible hinge is traced in Fig. 6 (dotted line).

The second candidate profile will not be fully disclosed, due to the firm intention to protect the new conceived idea. With the aim of showing the input data to calculate the VAM through both the metrics, the combination of FAF actions and feature classification is depicted in Table 11. The results about the expected success of the new profiles are reported in Table 12.

Both methods assigned the first product profile a good probability to thrive in the market, whereas the second one was supposed to be successful according to the Neural Network, but a failure with regards to the Logistic Regression. According to the coherent indications about the profile 1 and the uncertain outcomes concerning the alternative value proposition, OTLAV decided to focus primarily on the embodiment of the self-closing hinge.

Hence, through a problem solving approach based on TRIZ, the concept was refined by overcoming the technical contradictions arising during subsequent product development stages. The collaboration between the authors and OTLAV was concluded with the detailed design of the self-closing hinge, resulting in a filed patent application (IT-UD2011A000160, Assignees Politecnico di Milano and OTLAV) and a forthcoming exposition at an international sector fair.

Table 11
Four Actions Framework and TRIZ functional classification applied to the definition of the second innovative product profile.

Profile 2: Innovative concealed hinge	
Create UF	Create UF
Reduce UF	Reduce UF
Reduce RES	Eliminate UF
Eliminate UF	

Table 12
Estimation of the market potential of the proposed product profiles through the VAMs.

	Profile 1: Self-closing concealed hinge	Profile 2: Innovative concealed hinge
VAM (reg)	97.5%	33.4%
VAM (NN)	62.3%	76.0%

It has not been possible so far to evaluate the actual commercial response to the product, because of the early stage of its market entry. However, a survey conducted among door producers and dealers confirmed the potential appreciation from the market, since the totality of them showed interest in the product after an accurate description of its features.

5. Discussion

The article proposes the employment of categories (FAF and functional features) capable to represent, in abstract terms, any meaningful modification occurring to product profiles within innovation initiatives. The procedure for calculating the success chances of new value profiles requires the definition of the product attributes that have been modified with respect to the standard of the market, their identification in terms of the appropriate BOS actions describing the occurring transition and their classification in functional terms. According to the experience of the authors, the classification scheme is adequately comprehensive and non-ambiguous, such that parallel analyses performed by different researchers led to convergent scenarios. Nevertheless, the proposition of this classification scheme to students and colleagues has shown that beginners might encounter some difficulties, with consequent emerging ambiguities in the resulting analysis. From this perspective, further investigation is then required to assess the impact on the outcomes provided by the VAMs of any improper attribution of actions and functional features to describe changes of product/service profiles.

The outcome of the present investigation represents a first step in evaluating to which extent transformations in the intrinsic value properties of a product or a service impact their commercial destiny. Nevertheless, the authors are aware that such elements cannot explain by themselves the future success or flop of value transitions. This is particularly true with respect to the huge amount of other factors related to the management of innovation projects which are viable to twist objectives and schedules of product development initiatives. The high quantity of phenomena influencing the outcomes of an industrial innovation pipeline is discussed by a large literature: many contributions highlight and discuss the complexity of the mechanisms that underpin product development tasks. Among the others, the endeavours of some scholars are directed towards the employment of chaos theory to monitor the efficient organization of ongoing innovation initiatives [76,77].

In the plethora of the factors (and their mutual interplays) that influence the success of innovation projects, the proposed model tries to exploit the information generally available at the very early stages of the design process, i.e. when the needs to be satisfied and the reference market are elicited. From this point of view, the decision support provided by VAMs framework may be advantageously expanded by refining the values of success probability when additional information concerning the advancement of the innovation project is acquired. In other words, the index of success likelihood could be continuously updated as the design cycle progresses up to the launch and diffusion in the market, whereas dedicated forecasting techniques (mostly based on time series) are acknowledged to describe the varying rate of adoption for innovative products [42,78].

As clarified in Section 2, the presented evaluation metrics aim at addressing a specific deficiency concerning customer-oriented systems for supporting intelligent decision making during the early stages of NPD initiatives. The positive outcomes obtained so far, as reported in the previous section, constitute a practical demonstration of the possibility to pursue this objective with high expectations in terms of impact in the industrial practice with reference to the earliest stages of product planning.

However, with respect to the remaining research issues raised in Section 2, i.e. elicitation of unspoken needs and dynamics of customer preferences, some remarks have to be pointed out.

As assessed by the developers of the Kano model (e.g. [79]), changes in customer inclinations typically result in modifications of the importance and role assigned to product attributes in determining the perceived satisfaction. With regards to the dynamic nature of customer tastes, it is argued if such transformations dictate just slight adjustments of products performances [80] or rather pace the emergence of drastic innovations [15]. The authors share the vision of those scholars who believe that the phenomenon (at least in the forms observable through market surveys) is relevant within the same generations of products, whereas the bundle of significant customer requirements does not vary with respect to the industrial standard and no radical innovation is observed.

On the contrary, VAMs are built upon NPD initiatives pertaining disruptive modifications of product profiles that switch the main dimensions of customer value. Additionally, they swivel on the occurring changes with respect to industrial standards. Thus VAMs monitor in different terms the transformations of customer priorities. According to this evidence, it can be inferred that the field of application of the proposed metrics is restricted to the domain of new product development initiatives aimed at obtaining radical innovations. In such context, since the dynamic behaviour of customer preferences loses the original meaning, it does not affect the reliable application of VAMs for the purpose of preliminary assessing the success probability of a radically new product idea.

In a broader perspective, the subjects related to the exploitation of the seeded needs and the tendencies of changing customer orientations result relevant to value innovations from a different viewpoint. Further studies should answer the questions that follow. Were successful NVP initiatives capable to fulfil not explicit needs? Did they conversely induce major alterations of customer preferences by rethinking product profiles? Did they exploit changing conditions in the society, discontinuities in the marketplace, technological breakthroughs? To which extent were the previous factors influent in the achievement of success? How important were, at the time of formulating NPD objectives, the key product attributes subjected to main transformations in the definition of new value profiles?

The last issue can be barely introduced by discussing the NVP experiment related to the cosmetic industry, since it was preceded by the assessment of the importance of the customer requirements (Fig. 2). The first and second profiles for a new lipstick, which are deemed to be promising with regards to both the VAMs and the outcomes of the survey with potential customers, mainly emphasize the variability of the colour and the look of the packaging, respectively. Such features deal with product attributes accounted of very different levels of relevance for the clientele. This circumstance, to be verified in future works, suggests that valuable NVP initiatives can arise by stressing customer requirements characterized by varying importance levels.

In any case, a large set of explanatory customer-wise variables could be evaluated in order to better predict the success of innovative products, in addition to the relevance attributed to determine satisfaction. The preliminary step towards the achievement of reliable metrics, described in the present paper, has anyway given rise to plausible results, as witnessed by the cross-validation and the industrial applications. The fact is confirmed by insights about the VAM (reg) formula and more specifically to the algebraic sign (+ or −) of the coefficients associated to the couples composed by Actions and functional features. The resulting model complies indeed with the assumption that value-adding actions (i.e. Create and Raise) concur to generate successful product profiles, whilst the others combine to increase the probability of failure. The VAM (NN) confirms the high potential of techniques based on Neural Networks to account for complex relationships among variables, but it does not allow more careful considerations with regards to the above issues.

6. Conclusions

Building a metric to anticipate the market value of a product as a function of its properties might sound as a chimera. In order to bridge the gap between the current state of the art and such overall goal, the present article analyses the impact of a set of explanatory variables, concerning the transformations observed with respect to previous industrial standards.

The proposal swivels on a generalization process of the product attributes which contribute to the customer satisfaction by enhancing the provided benefits (Useful Functions) and reducing the related undesired consequences (Harmful Functions and consumption of resources). The developed techniques, namely Value Assessment Metrics, additionally exploit the logic of Four Actions Framework. The terms of FAF describe the transition from the product profile (i.e. the bundles of product features participating to customer satisfaction) representing the industrial standard to an innovative set of competing factors and associated performance levels.

A preliminary assessment of the perceived value is made through an abstract comparison with respect to past market success stories and failures, by surveying the kind of customer needs mainly impacted by almost a hundred innovative designs (both successful and failed innovations). The subsets of the whole sample devoted to the cross-validation experiment showed encouraging results about the usability of the proposed approach. On the basis of such study, the VAMs provide consistent indications about the expected approval of potential buyers and consequently the success likelihood of any product platform.

The outcome of this research represents thus a valuable support for strategic product development activities. In larger companies, the VAMs can provide an additional criterion for evaluating which product alternatives are majorly worth of investments. In smaller organizations strategic decisions (both related to market and technology) are often taken by the entrepreneur and/or by his/her closer collaborators, just on the basis of intuition. In such contexts, the VAMs can result as an implementable decision support procedure, requiring basic ICT infrastructures and skills, warning about the potential failure of innovation initiatives.

Two alternative metrics for the VAMs have been illustrated, based on Logistic Regression and on Neural Networks respectively. According to the outcomes of the experimental applications reported in this paper, both the modelling approaches appear as suitable to reach the target of the present research: Logistic Regression results less time consuming once the reference sample is defined, while the reliability of the Neural Networks seems to be less sensitive to the size of the sample itself.

The authors are aware that the proposed metrics need to be further validated and probably enhanced through a more extensive analysis of other case studies. At present, the application of the VAMs results relentlessly more reliable for those kinds of products and services which more abundantly populate the sample of successes and failures, e.g. mass-marketed artefacts, ICT systems, innovations from food and beverage, transportation and entertainment industries. Furthermore, it has to be noted that VAMs have been derived through the analysis of the value shifts characterizing successes and failures with respect to acknowledged products/services in the market; hence, the applicability of the proposed prediction model is restricted to those industrial domains where one or more standards are well-established.

The authors would be glad to share the details of the present research activity with other colleagues in order to extend the analysis to a larger number of case studies in the perspective of improving the forecasting capabilities of the developed instruments and expanding their domain of application. In this sense, a not negligible hurdle is represented by the lack of well-documented market failures concerning cases of value redefinition. Beyond the measures to overcome the weaknesses highlighted in Section 5, a further direction of research is constituted by investigating the role of the intrinsic nature of products, for instance by distinguishing between artefacts fulfilling primary necessities and those related to less urgent expectations. Maslow's hierarchy of needs and its redefinitions [81] might be relevant classifications to provide a better understanding of the phenomena allowing to design successful industrial artefacts. Other criteria could result likewise valuable to categorize the new value profiles and to be employed for evaluating the consistency of success anticipation metrics.

Within engineering design, the introduction of reliable methods for the definition of a new product can provide benefits for organizations in terms of reducing the waste of resources for the development of poor-valued projects. The proposed tools, as documented in the case study of the innovative concealed hinge, can be employed to select promising value propositions among previously defined alternatives. In this sense, the illustrated instrument does not ensure to detect the best option ever to direct the NPD task. The criteria for the value assessment represent thus metrics for supporting decisions, but do not work as a proactive system. However, by observing the extent of the coefficients of the VAM (reg), a designer can try to direct the innovation efforts towards the most value-adding directions. This kind of approach has not been tested, as well as the built value profiles presented in the paper (pertaining both the lipstick and the hinge) result by exploring the design space of viable solutions.

According to the above-explained limitations, the present research partially addresses the objective of supporting the NPD process from the viewpoint of reducing the resources channelled for scarcely promising design projects. Advances of the current study have to aim at better exploring the feasible solutions and consequently increasing the efficiency of the overall product cycle by bridging the development phases.

This could be achieved also through the support of other techniques, as those described in [3], leading to the generation of a better defined product profile expected to get a positive response by the market. In each case, it may happen that the innovative product profile is not straightforwardly implementable due to some technical, possibly inventive, problems to be solved. Besides, also in this case, an explicit formalization of the product objectives is an essential step towards a proper problem formulation. Moreover, the identification of conflicts between the product attributes can be directly approached as a TRIZ contradiction also thanks to the preliminary classification in terms of useful functions, harmful effects and employed resources.

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SUPPORTING THE CHOICE OF DESIGN ALTERNATIVES UNDERLYING INCREMENTAL AND RADICAL INNOVATIONS

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Keywords: decision making, competitive advantage, radical vs. incremental innovations

1. Introduction

The so-called Fuzzy Front End of engineering design cycles, i.e. the commencing activities, is acknowledged as the most crucial task to the purpose of developing innovative and successful products. As reported e.g. in [Duffy et al., 1993], 60-80% of whole design costs are committed in the initial product development stages. The first step of said innovation initiatives is the product planning, which gives rise to general, sometimes vague or abstract, product ideas. Such ideas are defined in terms of the new user needs they aim at fulfilling if they consist in radical redesigns of existing products. Otherwise, if the intent of the innovation process consists in less dramatic changes, objectives are posed in terms of the deliberated improvements. Anyway, no information is available yet with respect to exploited technologies and detail aspects (e.g. subcomponents, optimization of design characteristics).

The decisions to be undertaken with respect to product ideas are thus viable to jeopardize whole innovation processes and even the destiny of enterprises. In addition, the tackling of these choices consists in considerably complex activities [Montagna, 2011], because the product features and performances to be considered are hardly comparable. In other words, difficulties arise as a consequence of the lack of information and the presence of uncertainties taking place in initial product development stages [Herstatt et al., 2004; Paasi et al., 2008]. It is therefore claimed that the ability to rapidly and proficiently evaluate and choose alternatives represents a fundamental skill of designers [Ayağ and Özdemir, 2007]. However, it is widely recognized that designers and decision makers, even talented, are affected by subjectivity due to individual beliefs, background and values and that, as a consequence, their evaluations can result biased and erroneous. A recent research reported in [Kudrowitz and Wallace, 2013] documents how experts tend to intuitively select product ideas characterized by remarkable novelty, but by arguable utility.

On the basis of the recalled limitations, the paper proposes a methodology to select product ideas that firms intend to develop after the preliminary consideration of projects' feasibility and overall sustainability (e.g. in economic terms or from the viewpoint of the ecological footprint). The methodology exploits information usually available after the planning phase and that attempts to minimize experts' or decision makers' personal preferences. The required data that allow the working of the tool stand in variables which are supposed to play a significant role in determining the future market success of new products. The authors are aware that other factors will contribute to enable the success of innovative artefacts, as well as organizations have to carry out with not minor care the subsequent design phases up to the market introduction. Nevertheless, in light of the mentioned complexity and lack of information, the employment of significant indexes is limited to the determinants of customer satisfaction and to the aspects majorly valued by product users. In order to

face different circumstances that can be encountered in industrial contexts, a particular objective of the proposal is the capability to individuate the most advantageous ideas in a sample of candidate alternatives including incremental product enhancements, radical innovations or a mix of them.
Section 2 highlights additional deficiencies of existing methodologies and justifies the choices that have been made to build the proposed instrument for decision making. Section 3 describes the developed decision support tool and clarifies how to select the best alternative within any set of sustainable and feasible product ideas. Section 4 illustrates a test of the proposed methodology that employs a case study from the cosmetics industry. Discussions and conclusions are entrusted to Section 5 that ends the manuscript.

2. Overview of decision supports for product development initiatives and methodological objectives to be pursued

The present Section elucidates the basic issues that have motivated the building of an original approach to support the selection of alternative product ideas. The present overview attempts to remark the main limitations of the methodologies proposed in academia, which hinder their diffusion in industrial environments [Lopéz-Mesa and Bylund, 2011]. Whereas a complete state-of-the-art analysis is out of the scope of the paper, the acknowledged shortcomings of structured models have been considered as a starting point of the research.
Although not being recent by now, a reference survey about decision-making for product development initiatives is still represented by [Krishnan and Ulrich, 2001]. The investigation structures the various decision methods in terms of the different design stages they support. The initial product development tasks involve basically decisions about the target values of the fulfilled customer requirements. In a certain sense, the reviewed approaches are constrained to aid choices concerning product optimizations and consequently poorly contribute to the objectives of the present work.
More recent reviews (e.g. [Nikander et al., 2013]) show how most of the systematic selection methods consist in multi-criteria decision-making systems. They stand in models that consider a wide variety of technical and economical variables in order to identify the best performing alternative. Although such systems aim at making the choices more objective, it cannot be excluded that designers adapt the relevance of evaluation criteria in order to justify their initial preferences. Not surprisingly, experiments document how designers usually employ multi-criteria selection methods in an unstructured way and sometimes contradict their initial intent with the choices they perform [Nikander et al., 2013], as well as decisions are influenced by not formally defined factors [Kihlander et al., 2008]. In addition, weaknesses are witnessed about the lack of clarity in defining evaluation criteria that further limit the applicability of structured decision methods in the business practice [Messerle, 2013]. According to the above evidences, the authors opted to avoid the scheme of multi-criteria approaches.
In order to define the basic features of an original decision support tool, a first choice has to be made by evaluating pros and cons of quantitative and qualitative methods. Whereas the former provide numeric indexes characterizing the goodness of ideas and solutions, the latter basically suggest the means through which to compare the proposed alternatives. On the one hand, experiments in industry show how there is not a shared preference towards quantitative or qualitative/intuitive approaches [Kester et al., 2009]. On the other hand, many contributions turn qualitative measures into quantitative variables for the scopes of easing selection tasks [Erol and Ferrell Jr., 2003]. As straightforward, this practice does not solve subjectivity issues, which majorly stem from not measurable variables associated to qualitative information. Hence, whereas quantitative indicators identify more clearly the most beneficial product options, the objective is jeopardized if the computation of the performances employs terms characterized by high subjectivity and variability. In this context, the authors decided to examine the possibility of exploiting measurable or little subjective terms highly influencing the potential success of product innovation initiatives. The main object of investigation is therefore the individuation of the main success factors determining the end result of new product development tasks.
According to literature, commercial success is primarily sustained by internal collaboration between different units of the company and the attention dedicated to manifold organizational issues [Ayers et

al., 1997]. The collaborative knowledge management across product development teams is seen as a primary source of sustainable competitive advantage in [Ramesh and Tiwana, 1999]. The relevance of the relationships among different design teams is stated also in [García et al., 2008], which claims the positive effect of trust in fostering cross-functional integration. Other organizational issues and peculiarities of firms are considered as determinants for new products success in [Sohn and Moon, 2003], shedding light on the role played by technological level, R&D effectiveness, managers' experience.

The above contributions pinpoint the organizational aspects and the required human resources that favour the display of fruitful and lucrative innovation projects. However, these aspects concerning innovation processes cannot be taken into account when product ideas or concepts have been designed within the same organization. Hence, decisions would be advantageously supported by taking into consideration features regarding the proposed products rather than the ways innovation processes are carried out. In this sense, the capability to generate customer satisfaction can be considered as a shared dimension that strongly influences the success probability [Pettijohn et al., 2002; Huang et al., 2004, Albers and Clement, 2007] and capable to characterize the performances of products. Nevertheless, it has to be remarked that no available source (at least in authors' knowledge) has quantitatively assessed the influence of customer satisfaction in determining the success of new products. Further on, several scholars (e.g. [Christensen and Bower, 1996]) argue about the efficacy of enterprises whose mission is the achievement of customer satisfaction and that strictly adhere to the indications provided by consumers.

Within the support of decisions, customer satisfaction can represent however a basic criterion for selecting the most beneficial alternative without becoming a guiding principle for the firm. Its determination through quantitative terms represents however a not trivial task, especially in the treated case whereas products to be assessed have not been launched yet and subjective evaluations have to be limited. The estimation of potential satisfaction has then to take into account the fulfilled customer requirements, their performance and their influence in impacting users' value. Such an assessment approach is common in decision support methods exploiting Quality Function Deployment (e.g. [Li et al., 2012; Chen et al., 2013]), but in downstream product development stages and with a different aim, i.e. defining the measures of design variables in order to maximize customer satisfaction. An additional problem regards the possibility to assess or predict the role played by unprecedented product attributes. In other words, customer surveys can provide reliable information about the urgency and the expected impact of currently fulfilled product attributes, but may fail to assess the influence of new features generally characterizing radical innovations. Indeed, the literature clarifies how radical innovations, conversely to incremental improvements and optimizations, reconfigures the customer benefit landscape [Roy and Sivakumar, 2012] and undermine some of the basic assumptions validated by experience [Summerer, 2012]. In this sense, a further objective of the present work is the individuation of criteria capable to assess the expected value for customers descending from radical innovations. In other words, suitable variables have to be determined for both incremental and radical innovations, standing for the opportunity to develop the conceived ideas. The decision support tool has then to generate a unique coefficient characterizing any kind of innovation, which allows therefore selecting alternatives when the firm proposes a mix of product enhancements and brand new designs.

3. Methodological framework

As clarified in previous Sections, the objective of the paper is proposing a methodology to select any innovative product idea that has been advanced by an industrial subject. By considering the different dimensions impacting customers' perception of value when evaluating incremental or radical innovations, the authors propose tailored quantitative criteria to estimate the supposed competitive advantage provided by new products and a common term to compare the two clusters.

3.1 Estimating the enhanced perception of value generated by incremental innovations

Incremental innovations consist in moderate improvements of existing products and services regarding customer requirements the reference industry commonly competes on. Product users appreciate the generated performance enhancements, resulting in greater satisfaction.

The problem, from a methodological point of view, consists in relating the extent of improvements to the amount of additional customer satisfaction. It results straightforward that each product characteristic plays a different role in impacting customers' value. In addition, it has been demonstrated by Kano's theory of attractive quality [Kano et al., 1984], that the degrees of fulfilment of customer requirements can have non-linear relationships with the extents of consequently pursued satisfaction. This condition is particularly faced by product characteristics that customers explicitly suppose to find (must-be) and by unexpected properties and functionalities providing major satisfaction (attractive). The classical diagram underpinning Kano's model and the meaning of must-be, one-dimensional and attractive quality attributes, reported in numerous literature sources, are taken for granted for the purpose of the present work.
In each case, the curves drawn to explain Kano's model represent qualitative schemes and cannot be intended as quantitative representations relating product performances and customer satisfaction. The literature witnesses however several proposals attempting to establish quantitative links between the quality of product features and the resulting level of appreciation aroused by the consumers. Such literature contributions have been surveyed in [Borgianni and Rotini, 2013]. The cited work has indicated the model described by [Wang and Ji, 2010] as a reference for quantitatively associating the fulfilment of competing factors and the perceived satisfaction, because of its reliability and ease of obtaining the required data to build the representative curves. Such curves adopt the share of unsatisfied customers if a product characteristic is absent (*worse*) and exceedingly contented consumers if the same feature is fulfilled to the maximum extent (*better*) as the boundary points on the diagram ordinate, which stands for the liking level. *Better* and *worse* coefficients can be conveniently calculated, as proposed in [Berger et al., 1993]. Abscissas report the performances in charge of the diverse product attributes, for which an interval ranging from 0 to 1 is arranged. Curves are then drawn connecting the points representing the minimum and the maximum degrees of quality through lines with tailored trajectories. Whereas one-dimensional competing factors are schematized by means of segments (1), the curves underlying must-be (2) and attractive (3) features are described through exponential functions, as follows:

$$S = (Better - Worse) \times p + Worse \qquad (1)$$

$$S = \frac{e \times (Better - Worse)}{e-1} \times e^{-p} + \frac{e \times Better - Worse}{e-1} \qquad (2)$$

$$S = \frac{Better - Worse}{e-1} \times e^{p} - \frac{Better - e \times Worse}{e-1} \qquad (3).$$

In the formulas above, S represents the score of customer satisfaction generated by the product characteristic, according to its matching performance p.
In order to obtain the total amount of satisfaction stimulated by a product, it is hereby assumed that this index can be achieved by summing the partial degrees of contentment provided by each customer requirement. This approach is common in product innovation management literature, which witnesses several contributions (e.g. [Chen and Weng, 2006]) aiming at maximizing global customer satisfaction as a resultant of the level of attainment of multiple user needs. The sum of S variables stands thus for the whole capacity of a product platform to give rise to customer satisfaction. It then results that the chances of a new product to gain competitive advantage over the present commercial offer depends on the capability to generate greater customer satisfaction with respect to a supposed industrial standard.
In order to determine the opportunities of an incremental innovation to thrive in the marketplace, the authors propose to estimate its competitive advantage through an index named *appreciation level*, calculated on the basis of previous evidences and consolidated practices. The computation can be made in a step-by-step fashion, as follows:

- individuate and list the valuable competing factors for a specific product in a given industrial context;

- establish the degrees of fulfilment for all the listed customer requirements with respect to the proposed innovation(s) and a reference product supposed to be a standard for the market;
- characterize each product attribute in terms of Kano categories (must-be, one-dimensional, attractive) by means of tailored surveys (e.g. [Berger et al., 1993]);
- determine the *worse* coefficient, i.e. the share of drastically unsatisfied customers (with the sign -) for each competing factor, by hypothesizing that such product characteristic is unfulfilled;
- determine the *better* coefficient, i.e. the share of excited customers for each competing factor, by hypothesizing that the performance of such product characteristic is ideally high;
- obtain the partial shares of satisfaction *S* reflecting the performances of the incremental innovation(s) and the industrial standard by means of the formulas (1-3), which differ according to the deliberated Kano quality attributes;
- sum the previously calculated items in order to obtain the total amount of satisfaction referred to the incremental innovation(s) and the industrial standard;
- compute the *appreciation level* of the incremental innovation(s) as the ratio between its (their) global index of customer satisfaction and the one characterizing the chosen standard.

The last step determines therefore that innovations with *appreciation level* equal to 1 have no real competitive advantage, since they arouse the same amount of customer satisfaction generated by the industrial standard. At the same time, whereas such an index is lower than 1, the proposed incremental innovation represents a disadvantage in terms of competitiveness. The application of the calculation procedure will become more evident trough the experiment described in Section 4.

3.2 Estimating the benefits and the competitive advantage characterizing radical innovations

With respect to radical innovations, as clarified above, new product platforms drastically redefine the set of fulfilled needs that participate to the satisfaction of customers. A branch of literature is expanding devoted to support designers and entrepreneurs in carrying out innovation tasks leading to products and services capable to redefine market boundaries and hence to avoid severe competition (e.g. [Kim and Mauborgne, 2005]). Competing factors and their level of achievement, employed as fundaments to determine liking degrees within incremental innovations, cannot be considered anymore as means to compare different product profiles. This is due to the emergence of unprecedented product features that are supposed to consistently modify the impact of previously relevant properties [Tripsas, 2008].

Different explanatory variables have to be thus introduced in order to evaluate whether candidate breakthrough innovations are capable to obtain success in the marketplace, but little research has been conducted to clearly highlight such impacting factors. A contribution in this sense is represented by the work described in [Borgianni et al., 2013], whose objective is estimating the success likelihood of drastic product/service innovations in terms of the deviations from the commercial offer with regards to the benefits delivered to customers, users and service recipients. More specifically, the cited research computes the probability of radical innovations to thrive on the marketplace (named Value Assessment Metrics or briefly *VAM*) according to the diffusion of 12 different modalities in which the occurred transformations take place with respect to reference industrial standards. The 12 variables consist in the combination of the Four Actions introduced within the Blue Ocean Strategy [Kim and Mauborgne, 2005], i.e. the introduction of new attributes (Create), the exclusion of current competing factors (Eliminate), the significant growth/decay of performances (Raise/Reduce), and three kinds of benefits subjected to the above transformations. The latter are articulated in the so called functional features, standing in:

- direct advantages for customers or users (UF);
- the attenuation of undesired effects commonly associated with the functioning of the treated system (HF);
- the lessening of allocated resources or capabilities required to employ the product under investigation (RES).

The reference proposes to calculate the success probability through two alternative ways, i.e. a formula obtained through a regression model and a computer estimation performed by Artificial Neural Networks. The first option is preferable in order to allow any organization determining the *VAM* score, which is then calculated as follows, by computing beforehand the index *z*, which depends on the quantity of encountered transformations expressed in terms of pairs constituted by each functional feature and Action (4, 5):

$$\begin{aligned} z = &-3{,}19 + 3{,}44 \times UF/create + 1{,}32 \times HF/create + 2{,}87 \times RES/create \\ &+ 0{,}97 \times UF/raise + 1{,}75 \times HF/raise + 0{,}41 \times RES/raise - 0{,}84 \times UF/reduce \\ &- 0{,}27 \times HF/reduce - 1{,}78 \times RES/reduce - 0{,}46 \times UF/eliminate \\ &- 9{,}49 \times HF/eliminate - 1{,}65 \times RES/eliminate \end{aligned} \quad (4);$$

$$VAM = 1/(1+e^{-z}) \quad (5).$$

For instance, the consistent improvement of two useful effects (UF/raise) requires to add 0,97 twice for the computation of the *z* coefficient. Success probability scores have then to be transformed in terms of *appreciation level*, in order to make the comparison of radical and incremental innovations feasible. The rule to be followed is to assign the value 1 for such a coefficient to those product ideas providing no real competitive advantage with respect to the industrial standard. In the case of radical innovations, such “neutral” situation can be considered for product ideas showing 50% success probability (*VAM*=0,5). By doubling *VAM* index it is then possible to achieve *appreciation level* coefficients that represent positive (negative) effects on competitiveness when holding values greater (minor) than 1. In order to compute the *appreciation level* for each radical innovation, it is thus required:

- to list the planned changes in terms of benefits for customers or users with respect to the market standard of the reference industry;
- to describe such transformations through the Actions introduced within the Blue Ocean Strategy (Create, Raise, Reduce, Eliminate);
- to identify the proper functional features (UF, HF, RES) that characterize the product attributes subjected to the above Actions;
- to count the mutual relationships between Actions and functional features included in the list of modifications of the benefits, so to apply the formula (4);
- to calculate the *VAM* value as in (5) and to determine the *appreciation level* by doubling it.

4. Application of the decision support tool

The test of the proposed system for aiding the undertaking of decisions has been carried out by benefitting from a literature case study, whereas a mix of incremental and radical innovations has been already ideated and proposed. In particular, the exploited case study regards the development of four new alternatives pertaining to lipsticks for women’s make-up, whereas three product ideas represent radical innovations and have been already subjected to the computation of the *VAM* coefficient [Borgianni et al., 2013]. The distinguishing features of said radical innovations concern a vintage primary packaging, multiple colours that can be blended and a bigger stick, respectively.

No assessment had been performed conversely with respect to the incremental innovation, consisting in an elegant new lipstick owing the characteristics of L’Oreal Color Riche, candidate to become a successful product in the high-end market of cosmetics industry. In order to achieve the required data for computing the *appreciation level* for such a product, the authors obtained some information through the collaboration with an Italian enterprise manufacturing make-up lipsticks for famous brands. At first, the firm provided a list of the current competing factors in the lipsticks’ industry, resulting in a set of 21 customer requirements. All of them were evaluated in terms of their quality, performance or level of attainment with respect to their products (considered as a standard) and the innovation mimicking the proposal of L’Oreal. A Kano survey was then conducted to assess the relevance of each product characteristic and to determine the most suitable quality attribute of the same features. 25 managers and salespeople participated to the survey, providing all the needed data to calculate the expected competitive advantage for the incremental innovation, as shown Table 1.

Table 1. Assessment of performances and customer satisfaction for the proposed incremental innovation

				Standard lipstick		L'Oreal Color Riche	
Customer requirement	**Kano category**	***Worse***	***Better***	**Quality (*p*)**	**Provided satisfaction (*S*)**	**Quality (*p*)**	**Provided satisfaction (*S*)**
Stick colour	Must-be	-0,8	0,2	0,9	0,14	1	0,20
Stick colour precision	Must-be	-0,64	0,16	1	0,16	1	0,16
Stick taste	Must-be	-0,48	0,12	0,7	0,00	0,9	0,08
Stick scent	Must-be	-0,64	0,16	0,7	0,00	0,7	0,00
Absence of foreign bodies in the stick	Must-be	-0,8	0,2	0,8	0,07	0,9	0,14
Stick surface porosity	Must-be	-0,48	0,12	0,8	0,04	0,8	0,04
Lipstick applicability	Must-be	-0,64	0,16	0,8	0,06	0,8	0,06
Presence of active principles in the lipstick	Must-be	-0,48	0,12	0,7	0,00	0,7	0,00
Lipstick resistance on the lips	One-dimensional	-0,28	0,28	0,5	0,00	0,6	0,06
Avoiding irritation phenomena	Must-be	-0,8	0,2	0,6	-0,09	0,9	0,14
Quantity of product in the lipstick	Must-be	-0,48	0,12	0,6	-0,05	0,6	-0,05
Duration of lipstick properties	Must-be	-0,48	0,12	0,7	0,00	0,7	0,00
Customizable stick shape	Attractive	-0,16	0,64	0,2	-0,06	0,6	0,22
Special effects	Attractive	-0,16	0,64	0	-0,16	0,7	0,31
Compatibility of the primary packaging with the stick	Must-be	-0,64	0,16	1	0,16	1	0,16
Colour of the primary packaging	Must-be	-0,64	0,16	0,8	0,06	0,9	0,11
Resistance of primary packaging	Must-be	-0,16	0,04	1	0,04	1	0,04
Functionalities of primary packaging	Must-be	-0,64	0,16	1	0,16	1	0,16
Technical dossier	Must-be	-0,64	0,16	1	0,16	1	0,16
Product labeling	Must-be	-0,64	0,16	1	0,16	1	0,16
Cheapness	One-dimensional	-0,48	0,48	0,9	0,38	0,4	-0,10
TOTAL CUSTOMER SATISFACTION					1,23		2,05

For the sake of clarity, Kano categories represent the most diffused quality attributes as emerged by the proposed questionnaire, which revealed also the *worse* and *better* indexes, calculated as in [Berger et al., 1993]. The performances p of both the lipsticks have been assessed by the firm and are reported as *quality* in the Table. The customer satisfaction S generated by each product feature is computed according to the formulas proposed in [Wang and Ji, 2010] and expressed through (1-3). Eventually, the total amounts of customer satisfaction pertaining to both the industrial standard and the new product allow determining the *appreciation level* of the incremental innovation by simply dividing the global scores. The outcome is then roughly 1,67.

The values of the same index for the radical innovations can be trivially calculated by doubling the already available *VAM* scores, as indicated in Section 3.2. The verification of the reliability of the emerging outcomes can be made by using the results of a questionnaire, still included in [Borgianni et al., 2013], whereas 101 potential users of lipsticks expressed their preference with respect to any of the four proposed alternatives in light of the main product features highlighted in the questionnaire. The summary of the results is illustrated in Table 2, which shows both the final determination of *appreciation level* indexes and the number of preferences attained by each proposed innovation.

Table 2. Appreciation levels for the proposed mix of radical and incremental innovations

Innovation	*VAM*	Total Customer Satisfaction	Total Customer Satisfaction of the matching Industrial Standard	*Appreciation level*	Customer preferences
Radical 1– Vintage	0,97	-	-	1,95	23
Radical 2 – Multi-colour	0,86	-	-	1,72	42
Radical 3 – Bigger stick	0,15	-	-	0,30	10
Incremental – L'Oreal	-	2,05	1,23	1,67	26

Although the interview of a limited number of customers, constituting a sample of convenience, cannot be considered as a validation activity, some evidences arise from the analysis of the results shown in Table 2. A first remark can be made with respect to the most beneficial product innovation, showing a conflict between *appreciation level* scores and the quantity of preferences provided by the respondents. In this sense, the decision support tool would be deemed to select the wrong product idea, if customers' opinions are considered as a reference for the effective innovation success. However, it has to be highlighted that the values of the supposed competitive advantage concerning three alternatives (the first two radical innovations and the incremental one) are quite similar and reliable rankings cannot be performed in this case. Just one out of four *appreciation level* values substantially differs from the others and it refers to a product idea to be surely discarded according to consumers' preferences. Generally speaking, if the proposed system was not capable to clearly identify the most advantageous product alternative, it can be considered useful in discerning "good" from "bad" innovation proposals. This can be confirmed by matching the sets of values concerning *appreciation level* scores and customers' preferences, leading to a Pearson's correlation coefficient equal to roughly 0,72. In other words, the proposed decision system is deemed, for the given case study, to explain the future appreciation and success of innovative products to an extent greater than 70%.

5. Conclusions and future activities

The paper has illustrated a novel quantitative method for supporting decisions in industry, which combines in an original manner contributions aimed at quantifying the expected customer satisfaction and success chances. A distinguishing feature of the proposal is the employment of different metrics for estimating the goodness of radical and incremental innovations, since their appreciation is supposed to arise through dissimilar mechanisms. A particular objective of the work consisted in the limitation of decision makers' subjectivity that affects the choices performed during product development initiatives, even when using structured approaches. Within the proposed methodology a certain degree of subjectivity can regard the evaluation of product performances (when not directly measurable), which is a required step for assessing the competitive advantage of incremental innovations. However, the authors believe that this task, although not being error-free and unbiased, is not directly influenced by the individual preferences already conceived by designers when urged to tackle decisions about innovation projects to invest in.

The shown instrument for supporting decisions can be employed whenever a firm or a design team advances a set of new product ideas, whose main distinguishing features and benefits delivered to perspective users are well defined. The sample of proposals can include product profiles with extremely varying degrees of novelty. Decision makers have to identify an industrial standard in the industry they operate in order to evaluate the changes brought by each alternative. Therefore, limitations of the methodology regard its usability within brand new markets or whenever it is not possible to clearly identify the target performances of the new artefacts.

From the viewpoint of the benefits displayed by the illustrated design method, the system has demonstrated to basically select innovations viable to achieve success from probable flops. The first experiment has however led to partially satisfactory outcomes on the basis of the difficulties in identifying the most promising alternative. It has also to be noticed that the data employed for verification purposes cannot be considered sufficient for a full validation of the proposal, which would require to launch the new products in the marketplace and observe their real commercial results. Such a task cannot be currently performed due to long execution times and because it is preferable to fine tune the methodology prior to test it in such a hazardous situation.

Enhancements of the decision support tool are indeed expected. At first, the authors will try to further reduce the subjectivity of the required inputs, by establishing more systematic criteria to define performances and any other index whose designation would result poorly robust. Subsequently, a required test has to concern a sensitivity analysis with respect to the variability of the introduced coefficients and indexes. Whereas any variation would result exceedingly impacting with respect to the computation of *appreciation level* scores, measures should be taken in order to account for the uncertainty of terms employed to support decisions. Eventually, modifications of the methodology can regard the consideration of additional parameters related to the product showing a remarkable impact in determining future market success. In this sense, given the great influence of changing boundary conditions in product design contexts, authors are evaluating the opportunity to take into consideration the dynamic impact of product characteristics [Nilsson-Witell and Fundin, 2005; Tripsas, 2008; Chong and Chen, 2010].

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Innovation Trajectories within the Support of Decisions: Insights about S-Curve and Dominant Design Models

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ABSTRACT
The research about the patterns of technology evolution is populated by descriptive models, explaining quite regular trends of product development processes. The most popular schemes share the idea of long innovation periods characterized by incremental improvements and punctuated by technological turmoil events. Within the engineering field, such pattern can be described by S-shaped curves depicting the growth of performances in charge of technological paradigms, which approach their natural limit after entering their maturity stage. The birth of a novel S-curve symbolizes the emergence of a new breakthrough technology, which is followed by the choice of a preferred paradigm in the industry, generally designated as Dominant Design. However, new exigencies expressed by practitioners have remarked the limitations of qualitative models. Whereas some contributions openly question the general validity of the described models, a remarkable amount of literature claims that certain conditions related to the innovation processes have to be respected to make the outlined frameworks be valid. A deeper understanding about the open issues raised by the paper would result in more conscious innovation practices. Indeed, the exploitation of reliable models pertaining innovation trajectories could result in assessing the advantages arising by introducing new product functions or characteristics, enhancing performances on which industry is currently competing, reengineering manufacturing processes.

INTRODUCTION

The successful accomplishment of innovation initiatives nowadays represents a fundamental issue for safeguarding companies' competitiveness. Especially in shrinking markets, the capability of introducing original and valuable goods or services is a key factor for the success of enterprises. Besides, the literature shows how several features concerning the history of technologies impact the destiny of innovative products in the marketplace, often due to regularities observed within products evolution.

Several decades of research in product innovation trajectories have led to descriptive models, depicting general trends observed in the industry. The most popular models can be identified in the *dominant design* framework, introduced by Utterback and Abernathy [1] in the mid-70's and the *S-curves of technological substitution*, brought into the sphere of technical disciplines by Foster [2] in the 1980s. Although developed in different contexts, they share the idea of long innovation periods characterized by incremental improvements and interrupted by technological turmoil events. The relevance attributed to such frameworks has pointed the attention of scholars to development cycles alternating the main focus on product architectures and on industrial processes, as well as, on the growth of systems' performances. Few subsequent literature contributions about patterns, measurement, or categorization of innovation have neglected the insights emerging from these models. The debate, involving the fields of both industrial engineering and business management, has centred on the additional features required to characterize the phenomena related to innovation processes and the timing of technological discontinuities giving rise to product breakthroughs. Section 2 outlines a shared vision about the characterization of innovation tasks, which comprises the S-curves and the dominant design model.

In light of the above mentioned regularities, the knowledge about innovation patterns may constitute one of the key elements for building decision support tools aimed at increasing the success chances of new products and services. Conversely, models of products evolution have not impacted neither the dedicated literature, nor the industry, in terms of contributing to support decisions about innovation initiatives. For instance, no paper included in the acknowledged journal “Decision Support Systems” edited by Elsevier mentions the Abernathy and Utterback’s framework, while few contributions make reference to the S-curves besides in a different context other than technological change [3]. Akin results can be observed by scrutinizing the “International Journal of Information Technology & Decision Making” from WorldSciNet or the “Journal of Cognitive Engineering and Decision Making” published by Sage.

The authors have surveyed the literature in Section 3, with the aim of elucidating the possible reasons of the misalignment between promising makings (in theory) and poor practical results. Since authoritative reviews about the dynamics of innovation have been reported in several articles [4,5] a detailed state of the art review is beyond the scope of this paper. The work discusses major limitations, lacks of knowledge and still not addressed research issues that hinder the exploitation of the above models to support decision processes with regards to the most beneficial innovation strategies in industrial environments. According to the outcomes of this survey, the authors express in Section 4 their point-of-view about the main research issues worthy of future investigation. Finally, Section 5 presents the authors’ intentions about fine-tuning the metrics to quantitatively assess the worthiness of innovation initiatives.

2. RADICAL AND INCREMENTAL INNOVATION: FUNDAMENTAL MODELS AND SHARED KNOWLEDGE

In the debate about innovation in industry, one of the hottest topics has been the clash between two different schools of thought with respect to the main drivers dictating the development of innovations: technology and/or market. Despite the milestones of the discussion are quite dated, the argument is far from being archived and it seems reasonable to suppose that market-pulled and technology-pushed forces coexist and influence each other. For instance, Sahal [6] individuates the determinants of innovation in both socio-economical needs, leading to the emergence of new requirements, and technological developments, with a consequent interplay between them. Van den Ende and Dolfsma [7] argue that the development of technologies and the emergence of new paradigms is a fluctuated effect of technology-push and demand-pull factors. Whereas advances in the state-of-the-art technology enable product improvements or the building of original physical artefacts, the quantity of potential adopters defines the demand and represents a proxy of the extension of a new market. More recently, Enzing et al. [8], through an analysis of the Food & Beverages industry in the Netherlands, affirm that the short-term success of new products is influenced by both technology-related and market-related activities. On the other hand, the short-term success of improved products is conversely impacted just by technological factors. In each case, both market and technology spheres play a significant role for the long-term success of improved products.

As well, advocates of market vs. technology primacy have disputed over the most meaningful influences of transformations in industry, a convergence seems to have been reached between different disciplines with respect to the characterization of innovation. Freeman [9] validates the coexistence of technological breakthroughs and incremental improvements. The representation of innovation, by merging both phenomena, is classically depicted through long incremental periods punctuated by abrupt discontinuities. The manifestation of radical innovations revolutionizes the performance of industrial products or redefines the dimensions of value that impact customer satisfaction, by enabling the fulfilment of unprecedented product attributes.

At least from the period of the above citation (1990s), talking about incremental or radical innovation has become a common lexicon of economists, business managers, and engineers. In the followings, the authors report some fundamental, almost unopposed and well acknowledged concepts about the different phases of the innovation paths. With the aim of recalling a general vision of the shared knowledge about the subject, most of the sources are not recent, but still deemed valuable for the reflections carried out in the present paper.

2.1 Trajectories of Technological Substitution

The limits of old technologies and the need to provide greater levels of performance push towards the adoption of the knowledge dispersed across different industrial sectors, giving rise to eras of ferment and thus to radical innovation. Such phenomenon is reflected in a well-established model, whereas the main performance of a system grows by following a logistic S-shaped curve [2] as a function of the research effort that has been dedicated to its development. When the system has reached its maturity stage, its evolution approximates a limit with hardly appreciable improvements. In this phase, the industry gradually adopts emerging new technologies, which are capable to overcome the previous performance limitations of the system. The phenomenon is graphically depicted, as shown in Figure 1, through the birth of a novel S-curve, which gradually grows till surpassing the performances of the preceding technology and gives rise to a period of turbulence, hence eventually to the discontinuity.

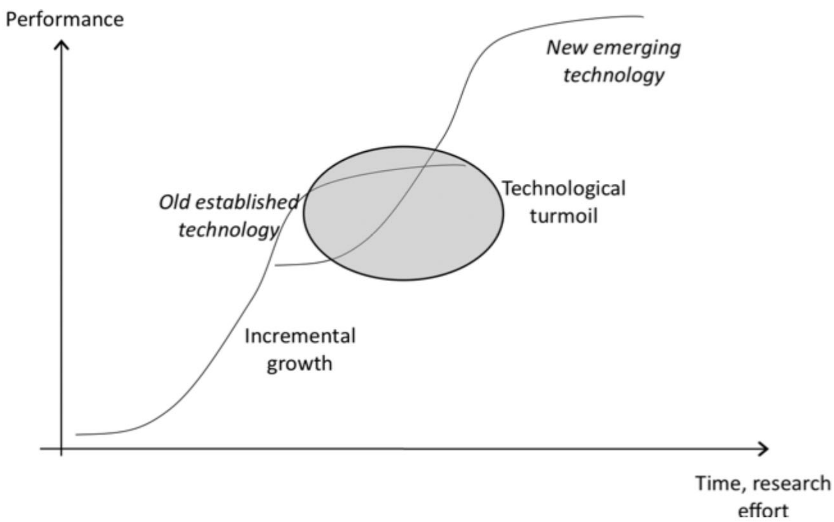

Figure 1. S-curve Model of Technological Substitution

According to a wider vision which considers multiple sources of improvement, the lifecycle of industrial products alternates the predominant relevance of performances and costs. Coherently with such perspective, the TRIZ (acronym of the Russian expression standing for Theory of Inventive Problem Solving) community agrees upon a modified S-curve, whose y-axis depicts a parameter named "Ideality". Such a term is defined as the ratio between the benefits provided by the useful functions of the system and the sum of the harmful effects and channelled resources [10]. According to the TRIZ Laws of Engineering System Evolution, each technical system evolves by maximizing its "Ideality" through an S-shaped path, by initially improving the useful functions, then decreasing the resources consumption and eliminating the harmful effects.

2.2 Innovation Stages during the Product Lifecycle

The dominant design model proposed by Utterback and Abernathy [1] somehow reflects a kind of lifecycle with a prior effort to maximize product performances and attractiveness and a subsequent phase dedicated to optimize industrial processes and hence to markedly reduce costs. Such phenomenon is depicted by the representative curves of the model, shown in Figure 2, which depicts the temporal trends of the innovation effort paid to improve products and the related manufacturing processes. The introduction of new technologies dictates the preponderance of the research on products, while the emergence of a dominant design acts as a breakpoint leading to the introduction of a standard architecture, thus reorienting industry investments towards the enhancement of processes with the objective of minimizing expenditures of organizations and time to market. In such a way the dominant design determines the end of turbulences that arise as a consequence of technological discontinuities [11].

Still according to Utterback [12], the breakthrough innovations of industrial processes are commonly in charge of incumbent firms, while drastic changes of products are diffusedly introduced by entrants. Afuah and Utterback [13] point out that, within discontinuity periods, the threat of incumbents is the greatest, since the "playing ground is completely levelled". In such turbulent circumstances the strategy of companies should be oriented towards the fulfilment of customers needs, especially those of lead users.

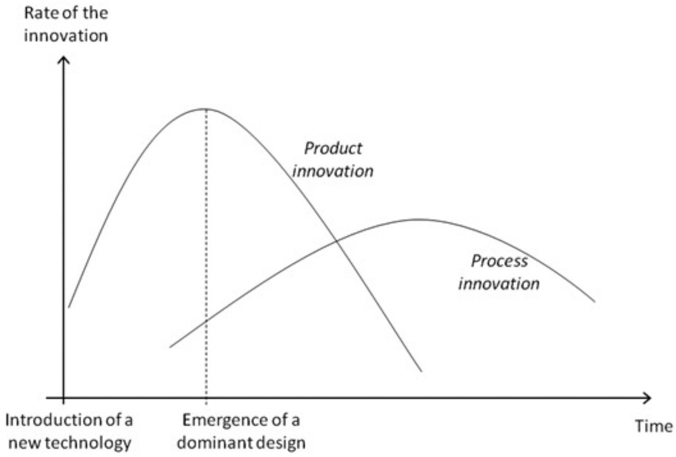

Figure 2. Innovation Timing according to the Dominant Design Model

The expected success and/or decline of firms reflects the most diffused school of thought about the destiny of incumbents and entrants in event of incremental and/or radical innovation. Tushman and Anderson [14] assess that technological breakthroughs can be both competence-enhancing (usually performed by incumbents) built on the accumulated knowledge and characterized by substantial increases of performance/price rates or competence destroying (commonly advanced by entrants) which produce a paradigm shift within the industry. The breakthroughs give rise to periods of technological turbulence and competitive uncertainty. Technological discontinuities represent a great source of competitive advantage for those firms willing to risk early adoption. In each case, all breakthroughs heavily influence the internal organization of enterprises.

In line with Anderson and Tushman [11], dominant designs commonly do not fully exploit the latest performance gains, falling far from the technological frontier. Furthermore, the scholars claim the greater length of ferment eras following competence destroying breakthroughs if compared with periods subsequent to competence enhancing discontinuities. During the evolution of industries, competence enhancing discontinuities result in diminishing turbulences. However, a dominant design appears each time a discontinuity takes place.

3. FUNDAMENTAL MODELS: CRITICISM AND LIMITS OF APPLICATION

As already recalled, despite of the large consensus attributed by authoritative researchers, the reference models describing innovation patterns have resulted poorly useful in the industrial practice. For instance, Dahlin and Behrens [15] point out that the known models are not to be employed in predicting tasks and that the distinction between incremental and radical innovations cannot be made at the time of market launch, since the future impact of new products and technologies is still unknown. Such considerations represent a severe hurdle in the context of the decision making process, especially if this is consciously oriented to produce breakthrough innovations.

3.1 Limitations of S-curves

Besides some examples fitting the trajectory of a S-curve, such model has been largely considered as a qualitative tool warning about the relentless appearance of radical innovations as time progresses. Nieto et al. [16], initially assuming the lack of theoretical rigor for S-shaped curves, remark how they are generally used as descriptive stand-alone schemes to highlight peculiar aspects.

Christensen [17] clarifies the boundaries for the employment of logistic curves of growth in the context of industrial innovation, by shedding light on the role played by component and architectural technologies. The above concept is introduced by Henderson and Clark [18], who focus on the knowledge enclosed in products, distinguishing between the component knowledge and the architectural knowledge. The former refers to the design of the constituent parts. The latter involves the way the components are linked together and implemented. Innovation patterns dealing with the redesign of components and assemblies can be characterized by a four quadrants graph, including incremental and radical, also modular and architectural innovation. Christensen [17] assesses that the use of S-curves by single companies for planning the development of component technologies or product architectures can result misleading. Along with the tacit reference of S-curves to the research endeavour of whole industrial domains rather than single enterprises, the main pitfall of such model stands in the moving limits of overall system performances, which can benefit from substantial and hardly predictable improvements of components exploiting immature technologies. Of course, such phenomenon delays the turmoil faced when completely new paradigms become dominant. At the same time, it results that first movers to new technologies have not generally experienced neither substantial performance achievements, nor market success.

As well as component technologies, architectural technologies follow the patterns of logistic curves [19]. Unlike advances in component technologies, architectural innovations are capable to explain the success of first movers, both in terms of performance and market results. Novel architectures determine the introduction of new dimensions of customer value, whilst underperforming well-established technologies, which conversely overcome market demand.

Sood and Tellis [20] argue about the extant assumptions behind the birth and the development of technologies, with a specific reference to the growth of performances. Based on the data collected about the performance of 14 competing technologies belonging to 4 diverse markets, some established principles are challenged. The data deny the S-shaped form of technological growth, depicting steep increases followed by long plateaus. Additionally, the surpasses of newer technologies on the old ones are multiple over the time. Some cases even show that the starting point of new technological paradigms can be positioned also above the current level of the preceding curve. In other words, the initial performances of new technologies are, in certain circumstances, greater than the old ones. Furthermore, whereas both entrants and incumbents can participate to the delivery of new technology, the major threats for established firms are represented by the emergence of new dimensions of the competition (i.e. the relevance attributed to different customer requirements), that often accompany the shifts towards new technologies.

3.2 Understanding the Role of New Product Attributes

Although the emergence of new dimensions of value, a possible way in which discontinuities take place, is capable to orient the buying decisions of customers, little research has been devoted to understand the impact of unprecedented product attributes on innovation trajectories. More extensively, Tripsas [5] argues that the available models describing discontinuities in product frameworks have neglected the dimension of customer demand and markedly the changing nature of users' preferences. Because of such lack, S-curves and dominant design frameworks (among the others) are not capable of explaining cases of abrupt systems transformations and products survival over the expected life. In this context, the discontinuities occurring in customer inclinations represent the catalyst for the introduction of a new technology in a given industry. Tripsas individuates several factors dictating the emergence of breakthroughs in customer perceptions: socio-political issues, interdependencies with systems at higher hierarchical levels, evolution of consumers' experience, media and advertising pressure proactively promoted by manufacturers. Thus, preference discontinuities intersect technological trajectories, giving rise to the eras of major ferment and the introduction of novel product paradigms. The occurred changes are highlighted by new product attributes, modification of the relative relevance among the set of fulfilled customer requirements, as well as by shifts of the minimum and/or maximum performance with respect to certain characteristics.

A greater amount of investigations are dedicated to point out how entrepreneurial [21] and organizational skills [22] enable innovation initiatives based on the fine-tuning of new products presenting original properties.

3.3 Enablers and Not-Deterministic Aspects of Technological Discontinuities and Market Adoption

The capabilities of companies and other aspects regarding the firm level are surely among the factors viable to influence the evolution of products and to make the technological substitution process a complex not-deterministic phenomenon. The presented models stand for a general tendency, but a considerable part of the phenomenon is still unexplained and unpredictable. In this sense, a vein of literature is devoted to map the preconditions that allow the display of the expected trajectories about innovation and market penetration.

By observing that eras of ferment are often very long periods of time, where competing technologies coexist, Nair and Ahlstrom [23] claim that some factors can be individuated to disclose the reasons of prolonged turmoil, otherwise described in literature as chaotic, random and stochastic. The conducted study investigates the steel making industry and the sector of kidney treatment. The paper identifies three factors viable to delay the affirmation of new paradigms: the complexity of the technology to be introduced, institutional dynamics and the ecological sphere. In this framework, "the emergence of an alternative and potentially superior technology does not necessarily mean the impending demise of the incumbent". The rapid growth and fall of technological concepts can be observed just within simple systems and components, whereas complexity conversely implies long turmoil periods.

According to the results of the survey carried out by Ortt et al. [24], the elapsed time between the introduction of a new breakthrough technology and the diffusion into mass markets can vary dramatically. Previously elaborated models foresee two phases, i.e. innovation and market adaptation, preceding the market stabilization, which follow a S-curved pattern to depict the penetration and the diffusion of a given technology. The initial phases are the most uncertain and market research studies, usually reliable just for the short term, give no practical indications about their duration and/or chances of technologies to reach a large diffusion. More markedly, most of the market researches are not suitable to assess customers' acceptance when the proposed set of attributes differs substantially with respect to the previous product profile.

Kaplan and Tripsas [25] point out the relevance of the cognitive dimension within the evolution of technologies, with a particular reference to the model of the dominant design. In the era of ferment, the endeavours of the actors within the industry are directed towards making sense of the new technology. The scholars state that, during this turmoil period, "in making decisions about which technology to pursue, firms incorporate their interpretations of the technology, of user needs, of their own capabilities and of the competition". The emergence of a dominant design is the result of a convergent process towards a given technological frame, involving consumers, producers and institutions. In this context, the capability of producers to promote a certain technological variant plays the greatest role if the whole technology lifecycle is considered. The wide stability addressed to the incremental era is the result of both organizational inertia and technological limits. In the moment of technological disruptions, entrants own the capabilities to visualize the opportunities and the superiority of the emerging technology.

In such amount of uncertainties and of factors to be monitored, the choices of decision makers are complicated by the rebounds of technological advancements on the marketplace, that can differ according to a plurality of factors characterizing customers and their environment. Dattée and Birdseye Weil [4], by criticizing the substitution models based on Bass diffusion frameworks because of lacks from the viewpoint of social heterogeneity, warn about the risk of misreading the market, e.g. giving up too soon or overconfidence. Eventually, Frenzel and Grupp [26] describe the patterns of alternative innovation diffusion models and explicate the determinants of their suitability with respect to the faced situation, hence denying the existence of a unified framework.

4. DISCUSSION AND AUTHORS' PERSPECTIVE ABOUT THE OPEN RESEARCH QUESTIONS

According to the outcomes of the investigation, the fundamental models of technological substitution should better define how to deal with a set of considerably impacting factors concerning the innovation process. In the authors' vision, the set mainly includes the hierarchies of the system (i.e. whole structure, parts, components) to be considered in order to discriminate between radical and incremental changes [5], the right locus of innovation (e.g. the firm level, the reference industry) to be taken into account [17] and the performances to be compared against within different generations of products [16].

A better comprehension of such issues could lead to the development of a shared model describing the evolution and the substitution of products and implemented technologies. Such a forecasting model with enhanced explanatory power may improve the capability of companies to establish the suitability of the innovations they propose and of technologies they originally employ. On the other hand, do new technologies just need to emerge or be implemented at the right time along product evolution cycles? The contents reported in Section 3 and additional contributions suggest different conclusions.

It is claimed that the large-scale adoption of new technologies is enabled by factors related to the market and the social sphere [23], as well as, by the availability of a sufficient accumulated know-how within incumbent and/or entrant companies [25]. A minor role is deemed to be played by the capability of new technologies to provide greater performance with respect to preceding paradigms [27]. Basically, an emerging technology has to be tailored to guide the generation of original business models or to express new meanings and new socio-cultural paradigms [28]. In other words, the technology has to ensure the fulfilment of new values for customer, embodied in original product/service attributes.

The above statement suggests, once again, that a major understanding would be welcome about the birth of radical innovations that change the reference evaluation parameters of a given product. The authors hypothesize that brand new triggers of value dictate, rather than the birth of a new S-curve with better performances, the generation of another diagram with the same shape, but with a different ordinate (i.e. a modified reference performance). However, such hypothesis represents just a possible outcome of the future research in the field. For instance, with a partially conflicting vision, the mechanism that dictates the implementation of new features in charge of changing technologies is seen by some scholars [29] as a more fluid and continuous phenomenon with respect to the abrupt modifications depicted in the discussed innovation trajectories.

Besides being the destiny of emerging technologies so relevant for understanding product development opportunities, it is expected by the authors that the backbone concepts of innovation trajectories will face a major harmonization with the findings from technology roadmapping [30]. Such a tool, that supports the planning of strategic decisions by linking technical and business-related aspects, is gaining popularity also as a support for forecasting disciplines [31]. A particular advantage from this research area could be obtained by those enterprises whose mission is continuous 360-degrees innovation. They would indeed benefit from individuating the possible destinations of emerging technologies and their potential market impact [32].

The importance of forecasting the future of new technologies is witnessed by the well known fact that many of them have been developed in certain industrial contexts and subsequently garnered success in completely dissimilar fields. Beyond not being bizarre, such phenomenon is consistently diffused [5] and basic for achieving solutions of a meaningful inventive degree with respect to the 5-level criteria introduced within TRIZ [33]. According to such criteria, inventions of levels 1 and 2 refer to trivial optimization solutions or relaxation of technical contradictions (i.e. the situations facing not mutual fulfilment of conflicting demands according to a predetermined paradigm) through the knowledge inherent to a given industrial domain. Conversely, the degrees of inventiveness 3-5 require inputs from different fields of science or even exploit discoveries, that provoke the disappearing of contradictions due to the observed paradigm shift. Consistently with the state-of-the-art reported in the present paper, the adoption of knowledge from a different scientific field should result in a competence-destroying change, dictating the technological turmoil and leading up to a radical innovation. The authors advance then a further research issue: are these suppositions correct? Can the level of inventiveness be associated with a certain kind of innovation? Upon the correctness of these assumptions, the fine-tuning of new technologies and the possibility to classify them according to the above 5 levels could tell much about their future, hence guiding the strategy of the organization which has developed them. Moreover, solutions with a substantially high level of inventiveness could result in candidate technologies for radical innovations with a soaring potential to impact future society if adopted in original business models.

5. CONCLUDING REMARKS AND FUTURE ACTIVITIES

The paper has critically discussed the main models describing the innovation patterns of industrial products, with a particular reference to the dominant design and S-curves of technological substitution, in order to evaluate the main reasons behind their missed implementation in decision support systems.

On the basis of the reflections and evidences reported in Section 3, it would sound reasonable to drop the attempt of designating the acknowledged trajectories of innovation as a starting point for the formalization of criteria to base industrial choices upon. Nevertheless, the authors believe that a huge amount of decision support systems are based on not more rigorous assumptions or not more reliable criteria, such as the outcomes of customer surveys. Beyond the fact that some decision-makers still take into account the dynamics of technological substitution [34] and efforts are dedicated to better manage discontinuities [35], the evidences from decades of research show how the evolution of products, architectures and technologies cannot be deemed just as a chaotic and fuzzy phenomenon. Although it could be claimed that the deterministic portion of the innovation process owns just scarce explanatory capabilities, such part could not be disregarded in order to partially "dissipate the fog" for companies willing to plan the development of new products or the reengineering of their industrial processes.

Besides attempting to contribute to the research issues outlined in Section 4, the authors are planning to deepen the preliminary attempts addressed at attributing a quantitative meaning to the discussed models for product innovation. They will then primarily exploit the hypotheses based on quantity and quality of patents to explain the course of S-curves [36], the dominant design paradigm [37] or any model describing technology lifecycles [38].

The final objective is to quantitatively assess, according to the current positioning along the curves for a given organization and in a determined industrial context, the appropriateness of alternative innovation actions (e.g. incremental improvement of an artefact, reorganization of the manufacturing process to gain efficiency, as discerned in [39]). On the basis of the uncertainty inherent to such kind of metrics, the estimation of a certain extent of variability has to complement the model for assessing such appropriateness and thus the consequent expected advantages in following any of the above innovation directions.

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Predicting the competitive advantage of design projects to dynamically support decisions in product development

Abstract
Many product development initiatives are planned on the basis of the supposed capability to generate customer satisfaction. However, market and technology conditions can undergo several transformation during the execution of product innovation projects and jeopardize the basic assumptions taken at the beginning of the design cycle. Among the changing factors, the observed alternation of radical and incremental transformations of product architectures is viable to influence the success chances of new products. Such an aspect is taken into account in the decision support tool described in the paper, which can be employed to select the most beneficial alternatives in a set of different product ideas.

Keywords: product evolution, decision making, product ideas, dynamics of customer requirements, customer satisfaction, dominant design

1. Introduction

As innovation projects give rise to a significant number of ideas, among which industries commonly own sufficient resources to further develop just some of them, decisions in the early stages of design hold increasing importance. Besides, decision makers are entrusted to complex tasks, since conscious design choices should take into account numerous intertwining factors (Montagna, 2011), which relate to both technology and market spheres. In detail, the difficulty of the task originates from the gap between the information required to evaluate design options and the available knowledge at the moment of selecting design alternatives (Herstatt et al., 2004; Medyna et al., 2012).
In order to face such a complexity, the most structured and diffused methodologies to aid the accomplishment of decision tasks refer to multi-criteria systems. Nevertheless, these tools are characterized by argued efficacy and often fail to overcome experts' subjectivity in selection processes. It then results that decisions rely to a great extent on qualitative evaluations and subjective judgments (Rosenman, 1993; Nikander et al., 2013). Personal conviction and the so-called "design fixation" (e.g. Atman et al., 1999), determined by individuals' background, beliefs and tastes, often make the decision process a very vague task, whereas even the evaluation of future market success is missing.
The situation is even more problematic if decisions have to be tackled in fast evolving industries or for long lasting innovation activities, since the relative importance of evaluation criteria for undertaking decisions undergoes fluctuations as time progresses. Such modifications do not deal just with variations of the boundary conditions in which innovations take place (social and political situation, technological breakthroughs, fashion trends, etc.), but also with the inextricable dynamics of customer preferences (Sood and Tellis, 2005). With the aim of managing the effects of alterations in industrial contexts and in the marketplace, models have been developed attempting to describe the historic transformation of products, regardless the causes provoking the changes. These models ground their roots in basic concepts about the varying degrees of innovativeness that are suitable according to the maturity of the products (Utterback, 1996) and consequently to the implemented technologies (Cascini, 2012).
In the given framework, the authors have investigated the dynamic phenomena affecting New Product Development (NPD) projects (Section 2) and how they are taken into account in systems and procedures for supporting decisions undertaking in industry. All the causes of dynamic behaviours have to be considered in a perspective decision support system, which represents the final goal of the present work.
According to the overview, the main methodological gap currently stands in the disregard of the above innovation cycles. The paper proposes therefore an initial decision support method for selecting alternative product ideas taking into account the above remarked limitations. The instrument, to be used in the initial stages of NPD cycles, is capable to exploit data about the basic properties of the proposed innovations by limiting experts' evaluations, which potentially give rise to biases in decision tasks . The proposal, which is illustrated in Section 3, takes into account both the dynamics regarding the evolution of industrial artefacts and the inherent differences between radical and incremental innovations. Section 4 describes how the decision support system has been tested, while the outcomes of the experiment are discussed in Section 5. Section 6 concludes the paper with the final remarks and future planned activities.

2. Dynamic phenomena affecting decisions in product development: major issues

It is well-acknowledged that market and technology conditions change along the execution of product development tasks. The transformations impact the success potential of new ideas defined at the beginning of design processes, since the planned product features can result unsuitable to meet customer satisfaction at the end of the NPD project. A common approach is monitoring, during the development activities, the variations of the drivers that impact customer satisfaction and updating, as a consequence, the product ideas. The modifications involve therefore the initial phases of design cycles which define the needs products should fulfil. It follows that the revision of the ongoing NPD process can result extremely costly, since the modifications of the decisions regarding the initial design phases are the most impacting in terms of project expenditures (e.g. Achiche et al., 2013).
According to several scholars (e.g. Chong and Chen, 2010a), neither academicians nor industrial practitioners have sufficiently taken into account the dynamic nature of the determinants of customer value, especially in light of the

above rebounds it can have on the efficiency of NPD initiatives. It would then result desirable to anticipate such dynamics, thus minimizing the changes to be subsequently brought in product ideas and concepts. In order to achieve this goal, it is required to analyze the different aspects that are subjected to transformations.

In the authors' vision arisen by browsing the literature, the dynamic effects that mostly twist the landscape of successful product platforms regard basically three different dimensions: current customer requirements, future needs to be fulfilled, the cycles that observe the alternation of moderate improvements and more drastic redesigns.

With respect to recognized customer requirements that shape the performance and the appeal of existing products, many methods and tools have been experimented to assess the changing extent of importance. Among recent contributions, the prediction of the relevance of different product attributes is performed e.g. by Chen and Wang (2008), that exploit grey theory and claim to perform good estimates by considering different customer clusters. The determination of the relative importance in a sample of product characteristics is a fundamental input for Quality Function Deployment (QFD), for which the first contributions to deal with dynamics of customer needs appeared already in the 1990s (ReVelle, 1991; Adiano and Roth, 1994) . In the course of time, QFD-oriented applications taking into account dynamic customer requirements have become more structured and sophisticated, by integrating, for instance, the capabilities of the Markov chain method (Wu and Shieh, 2006; Shieh and Wu, 2009), SWOT analysis (Raharjo et al. 2010a) , the Analytical Hierarchy Process (Raharjo, 2011), grey theory (Chen et al., 2011). Another acknowledged dynamic behaviour gaining increasing attention regards the changing capability of product attributes to avoid dissatisfaction by accomplishing basic functions and to provoke unexpectedness and excitement (Chong and Chen 2010b; Löfgren et al., 2011; Song et al., 2013a). More specifically, such a phenomenon regards the progressive transformation of the quality attributes defined by Kano's model (Kano et al., 1984), which puts into question the linear relationship between product performances and aroused customer satisfaction. The literature witnesses proposals to orientate decisions on the basis of the transitions expected by Kano's quality attributes (Sakao, 2009; Raharjo et al., 2010b).

The above methods which anticipate the impact of customer requirements share some commonalities, regardless they forecast the importance of product attributes or their influence on the different dimensions of satisfaction envisioned by Kano. At first, they basically require plenty of historical information about customer preferences in order to work correctly. In a second instance, the consideration of past and present needs might overlook the emergence of new customer requirements viable to noticeably affect the industry and the market.

The difficulties in foreseeing new customer needs seem to be well perceived in the business (Kärkkäinen et al., 2001). Chong and Chen (2010a) highlight the lack of methodologies capable of individuating future needs and state that relevant human efforts are required to continuously monitor the situation about the emerging drivers for customer satisfaction, despite the increased capabilities of ICT solutions and the large availability of data.

If the task of proactively proposing the right customer requirements for the future market is currently not supported, the relentless dynamics affecting product development and evolution can be taken into account to aid decision-making. In other words, whereas current instruments do not adequately guide towards the definition of original benefits satisfied by successful products, it would result useful to exploit seeded knowledge to individuate which innovative ideas are the most likely to thrive in the marketplace. Regardless the procedures and the tools managers or R&D teams follow to carry out NPD cycles, the generated new product ideas consist in frameworks that outperform known customer requirements (incremental innovations) or candidate breakthroughs attempting to satisfy unprecedented needs (radical innovations). The above discussed contributions can be straightforwardly applied to support decisions about the former, but do not own the means to evaluate the opportunity of developing the latter. Indeed, the literature clarifies how radical innovations, conversely to incremental improvements and optimizations, reconfigure the customer benefit landscape (Roy and Sivakumar, 2012) and undermine some of the basic assumptions validated by experience (Summerer, 2012). Such drastic changes produce severe discontinuities of customer preferences (Tripsas, 2008), which jeopardize prediction models based on historic data. In this context, the third kind of dynamics enunciated at the beginning of the Section, i.e. cycles of radical and incremental innovations, should be taken into account when needing to select product alternatives characterized by different degrees of newness. Borgianni and Rotini (2012) have pinpointed that the qualitative nature of innovation cycles and trajectories has caused a diffused scepticism about the possibility to exploit the underpinning models, although well acknowledged, for design decisions purposes.

According to the limitations arisen by the performed overview, the present work is aimed at fine-tuning a quantitative decision support system capable to help industries in selecting designed product ideas, which can refer to both incremental and radical innovations. The method presented in the paper, representing a first step towards the final scope of considering all the sources of dynamic phenomena, takes primarily into account the timing of innovation, as the most disregarded varying dimension.

An original decision support to be employed when companies have to select a product idea among a sample of alternatives, has thus to fulfil a set of requirements, including the capabilities:

- to guide the choice of the most advantageous product idea also in the simultaneous presence of incremental and radical innovations;
- to take into consideration the timing of market introduction, which can result more favourable for radical or incremental innovations;
- to lead towards choices by limiting the influence of decision makers' or experts' subjectivity.

3. Fundaments and description of the proposed methodology

With respect to the last requisite posed at the end of Section 2, the development of the system was oriented towards a quantitative decision support, whose outcomes, in the form of numbers, are not arguable. Of course, the restraint of subjectivity has to regard also the inputs required to perform the final assessments. The authors experienced the possibility to base the decisions on a numeric indicator, standing for the potential product success (*advantage* in the followings), that comes out as the combination of two different influencing factors:

- the goodness of product ideas in terms of fulfilling customer expectations and triggering consumers' delight in the current situation, without considering the dynamic phenomena affecting the market and the technology; the effect is evaluated through the coefficient named *appreciation level*, whose calculation considers the different aspects impacting customers' perception of value when evaluating incremental or radical innovations;
- the suitability of the kind of innovation (radical or incremental) when the design process is supposed to end, with respect to the historic evolution of the product framework: this source of success is expressed through a second coefficient, namely *pertinence*.

The following Subsections motivate the measures undertaken to determine the above indexes. According to such criteria, the whole decision support method is articulated as in the workflow reported in Figure 1. The letters in the cells represents the methodological steps and will be used in the followings to ease comprehension.

[Figure 1 about here]

Given the objective of treating in a suitable way both incremental and radical innovations, the original product alternatives to be selected have to be firstly classified according to one of the mentioned categories (steps *a.*).

3.1 Determination of the pertinence of radical and incremental innovations

As underlined above, the literature agrees upon evolving models of products. Long periods of moderate modifications and performance growth are punctuated by breakthrough innovations that totally redefine the competition and mark the beginning of new cycles. Discontinuities are characterized by significant technological turbulence and the proposition of many different product options, which feature dissimilar structures and delivered benefits. The turmoil is interrupted by the emergence of a successful product platform which best embodies the cues that have dictated the transition from the previous version of the artefact. The popular interpretation of the described cycle provided by Utterback and his colleagues (e.g. Utterback and Abernathy, 1975; Utterback, 1994) indicates with the term "dominant design" the winning variant that becomes the new reference for further product enhancements.

If the mechanism is acknowledged that periodically observes the alternation between radical and incremental innovations, there is no agreement about the factors capable to interpret the imminence of substantial transformations. Utterback's approach stands in the examination of the quantity of firms working in a certain industry and manufacturing a given product. Such a number of organizations follows a trajectory which can be approximated to a bell-shaped curve as time progresses. The flourishing of the industry and hence the boom of the quantity of enterprises roughly corresponds with the emergence of the dominant design, which subsequently marginalizes the companies not capable to adapt to the new reference product platform. The possibility to use the number of firms as a descriptor of the cycle's advancement is substantially hindered by the poor availability of such a kind of census data.

Alternative approaches to quantitatively interpret innovation cycles exploit technology indicators rather than business information. Within the forecasting capabilities of the Theory of Inventive Problem Solving (TRIZ), qualitative curves are introduced describing the life cycle of technical systems (e.g. Webb, 2002; Leon, 2003). The number of inventions is related with the level of the same inventions, hence with the degree of suitability of radical and incremental innovations. However, it is unclear how to measure the quantity of inventions, which do not exactly correspond with patents. Moreover, the TRIZ community has shown no quantitative example to state the validity of the cited curves, which thus linger in the form of an intuition of the theory's father, Genrich Altshuller.

Besides, Intellectual Property indicators are diffusedly used as a means to interpret technological cycles and hence the maturity of products. Their employment is advantageous, since many patent databases (even free of charge) are available on the web. Product and process patents are used in documented applications to explicate the patterns of systems lifecycles (Scherer, 1984) and more specifically Utterback's model (Mauri and McMillan, 1999). In this specific context, product patents are seen as major enhancements of the technical systems impacting the general characteristics and the delivered benefits. Process patents aim at optimizing the operations to manufacture the products and influence dimensions like quality, costs, dispatch timeliness. The major shortcoming of models exploiting the nature of patents is the crisp border between process and product inventions and the not negligible quantity of documents claiming improvements for both the aspects. Clymer and Asaba (2008) analyze the dynamics of the documents issued in the patent subclasses pertaining to the field of ink-jet printers in order to characterize the conditions in which dominant designs emerge. Unfortunately, the approach is domain-specific and it cannot be extended to other industrial contexts. Haupt et al. (2007) use various patent indicators to describe technological lifecycles and simplify the task by considering just outstanding assignees. However, the proposal suffers from missing a full validation, since the employed case study concerns an industry whose decline has not been observed yet. Jang et al. (2009) base the description of innovation cycles on the rates of patent forward citations, but the model does not fulfil the objectives of a decision-making system, since information about such indicators is not available at the time of the choice.

At the same time, the number of published patents (Agarwal, 1998) ranges among the underpinning variables capable to represent the model of product innovations diffusion developed by Gort and Klepper (1982), which is still debated and under refinement (Peltoniemi, 2011). Such a model, slightly differing from Utterback's reference, individuates five distinct stages of product evolution, from introduction and diffusion to obsolescence. Despite the quantity of patents roughly follows a bell-shaped trajectory (from initial inventions to product dismissal), the well-acknowledged model proposed by Agarwal (1998) approximates the curve with a parabola opening downward (see Figure 2).
[Figure 2 about here]
In order to determine the best approximation, the number of published patents has to be gathered and the introduction year is consequently deduced, standing for the beginning of the product cycle. A multivariate linear regression is then performed by linking the quantity of the documents with their age (i.e. the years elapsed after the introduction) and their squared age. For the purpose of observing the trajectory of the parabola, the approximation applies if:

- the regression coefficient associated with the age (b) is positive;
- the regression coefficient associated with the squared age (a) is negative;
- both coefficients are statistically significant.

Such an approach can be adopted for the scopes of the present work, given the large availability of the data and the possibility to describe innovation trajectories through quantitative terms. It is then required, for each product platform constituting a standard for the alternatives to be chosen (steps *b.* and *c.*), to retrieve the pertinent patents (step *d.*), determine the first year of the cycle (step *e.*), relate the age of the product with the number of inventions (step *f.*) and carry out the regression (step *g.*), so to obtain a and b coefficients (step *h.*), whose values have to be verified (step *i.*). According to the adopted model, the intersections of the parabola with the abscissa (represented by the age of the product) stand for the birth of the product and its predicted market extinction due to obsolescence and introduction of more evolved artefacts (Figure 3). It then results that the proximity to such intersections represents a particularly favourable period for the introduction of radical innovations. Indeed, the beginning and the end of the cycle represent the start of the technological turmoil and the impending transitions to novel product frameworks, respectively. On the other hand, the vertex of the parabola figures the stability of the product architecture, due to the emergence of the dominant design, and corresponds to the maximum suitability of incremental innovations.
These evidences are reflected in the choices for structuring the proposed decision support tool and more specifically for determining the variability of the *pertinence* of radical and incremental innovations with regards to the product development period. It is hereby hypothesized that both coefficients have a linear variation and that their graph describes therefore broken lines, as illustrated in Figure 3.
[Figure 3 about here]
According to the above criteria, the *pertinence* variables can be determined according to the following formulas (steps *j.* and *k.*):

$$\pi_r = |age_{inn} + \frac{b}{2a}|/(-\frac{b}{2a}) \quad (1);$$

$$\pi_i = 1 - \pi_r \quad (2),$$

whereas:

- π_r and π_i are the *pertinence* levels of radical and incremental innovations, respectively;
- age_{inn} is the time elapsed, measured in years, after the birth of the cycle at the moment of the supposed market introduction of the innovation;
- according to algebraic geometry, $-b/2a$ is the time elapsed, after the birth of the cycle, at the point of the vertex of the parabola.

3.2 Measures for assessing the appreciation level of incremental innovations
Incremental innovations consist in improvements of existing products regarding customer requirements the reference industry commonly competes on. Product users appreciate the generated performance enhancements, resulting in greater satisfaction. In order to evaluate the increase of satisfaction of a novel product idea with respect to existing artefacts is then primarily required to individuate the whole set of competing factors (step *l.*) and to assess their performances in the new and the old profile (step *m.*).
The problem, from a methodological point of view, consists in relating the extent of improvements to the amount of additional customer satisfaction. It results straightforward that each product characteristic plays a different role in impacting customers' value. As already mentioned with reference to Kano's model, the degrees of fulfilment of customer requirements can have non-linear relationships with the extents of consequently pursued satisfaction. This condition is particularly faced by product characteristics that customers explicitly suppose to find (must-be) and by unexpected properties and functionalities providing major satisfaction (attractive). Some basic concepts about Kano's theory are taken for granted for the purpose of the present work. They include the classical scheme underpinning Kano's model, the meaning of must-be, one-dimensional, attractive and indifferent quality attributes, the way to determine them as a result of appropriate surveys asking potential consumers about their feelings when customer requirements are fulfilled or unmet. The suggested reference is (Berger et al., 1993).
In each case, the curves drawn to explain Kano's model represent qualitative diagrams and cannot be intended as quantitative representations relating product performances and customer satisfaction. The literature witnesses however several proposals attempting to establish quantitative links between the quality of product features and the resulting

level of appreciation aroused by the consumers. Such literature contributions have been recently surveyed by Borgianni and Rotini, (2013), indicating the model and the equations described by Wang and Ji (2010) as a reference for associating the fulfilment of competing factors and the perceived satisfaction. The strengths of the model, which will be adopted for the building of the decision support tool, stand in its reliability and ease of obtaining the required data to build the representative curves. Such curves employ the share of unsatisfied customers if a product characteristic is absent (*DS*) and exceedingly contented consumers if the same feature is fulfilled to the maximum extent (*CS*) as the boundary points on the diagram ordinate, which stands for the liking level. *CS* and *DS* coefficients can be conveniently calculated, as proposed in the same reference (Wang and Ji, 2010) with respect to the answers provided to Kano's surveys (step *n.*), as follows (with respect to the *j*-th customer requirement):

$$CS_j = (f_{Aj} + f_{Oj})/(f_{Aj} + f_{Oj} + f_{Mj} + f_{Ij}) \quad (3);$$

$$DS_j = -(f_{Oj} + f_{Mj})/(f_{Aj} + f_{Oj} + f_{Mj} + f_{Ij}) \quad (4).$$

In the formulas (4) and (5), f_{Aj}, f_{Oj}, f_{Mj} and f_{Ij} represent the number of customers participating to the survey whose response about the *j*-th product characteristic has given rise to the attribution of attractive, one-dimensional, must-be and indifferent Kano categories, respectively. The abscissas of the curves report the performances in charge of the diverse product attributes, for which an interval ranging from 0 to 1 is arranged. The value 0 refers to unfulfilled customer requirements, while 1 stands for the best performance achieved within the competition. Curves are then drawn connecting the points representing the minimum and the maximum degrees of quality through lines with tailored trajectories. Whereas one-dimensional competing factors are schematized by means of segments (5), the curves underlying must-be (6) and attractive (7) features are described through exponential functions, as follows:

$$S_{oj} = (CS_j - DS_j) \times p_j + DS_j \quad (5);$$

$$S_{mj} = \frac{e \times (CS_j - DS_j)}{e-1} \times e^{-p_j} + \frac{e \times CS_j - DS_j}{e-1} \quad (6);$$

$$S_{aj} = \frac{CS_j - DS_j}{e-1} \times e^{p_j} - \frac{CS_j - e \times DS_j}{e-1} \quad (7).$$

In the formulas above, S_{xj} represents the score of customer satisfaction generated by the *j*-th product characteristic, according to its matching performance p_j. The selection of the tailored formula depends on the results of the survey: the matching quality attribute of a given customer requirement is assigned with respect to the Kano category obtaining the greatest number of indications (steps *o.* and *p.*). In order to obtain the total amount of satisfaction stimulated by a product idea, it is hereby assumed that this index can be achieved by summing the partial degrees of contentment provided by each customer requirement (step *q.*). This approach is common in product innovation management literature, which witnesses several contributions (e.g. Chen and Weng, 2006) aiming at maximizing global customer satisfaction as a resultant of the level of attainment of multiple user needs. Even if their contribution to satisfaction is marginal, indifferent attributes have to be however considered, so to take into account the disposition of those customers valuing product aspects poorly impacting in the market. Although such a kind of customer requirements are not treated in (Wang and Ji, 2010), formula (6) will be used to deal with indifferent attributes, by assigning them a linear relationship between quality and aroused satisfaction.

The sum of S_j variables stands thus for the whole capacity of a product platform to give rise to customer satisfaction. It then results that the chances of a new product to gain competitive advantage over the present commercial offer depends on the capability to generate greater customer satisfaction with respect to a supposed industrial standard.

In order to determine the opportunities of an incremental innovation to thrive in the marketplace, the authors propose to estimate its competitive advantage through an index named *appreciation level* (α_i), calculated as ratio between its capability to generate customer satisfaction and the one of the market standard. For the sake of clarity (step *r.*):

$$\alpha_i = \sum_j S_{j\_i} / \sum_j S_{j\_std} \quad (8),$$

whereas the subscripts *i* and *std* concern data about the incremental innovation and the industrial standard, respectively. The calculation implies that innovations with *appreciation level* equal to 1 have no real competitive advantage, since they arouse the same amount of customer satisfaction generated by the industrial standard. At the same time, whereas such an index is lower than 1, the proposed incremental innovation represents a disadvantage in terms of competitiveness. The application of the procedure to assess incremental innovations will become more apparent trough the workflow of the decision support reported in Section 3.4 and the experiment described in Section 4.

3.3 A strategy for assessing the appreciation level of radical innovations

With respect to radical innovations, as clarified above, new product platforms drastically redefine the set of fulfilled needs that participate to the satisfaction of customers. A branch of literature is expanding devoted to support designers and entrepreneurs in carrying out innovation tasks leading to products and services capable to redefine market boundaries and hence to avoid severe competition (e.g. Kim and Mauborgne, 2005). Competing factors and their level of achievement, employed as fundaments to determine liking degrees within incremental innovations, cannot be considered anymore as means to compare different product profiles.

Different explanatory variables have to be thus introduced in order to evaluate whether candidate breakthrough innovations are capable to obtain success in the marketplace, but little research has been conducted to clearly highlight such impacting factors. A first attempt in this sense is represented by the work described in (Borgianni et al., 2013), whose outcomes will be used for the purpose of the proposed methodology. The objective of the cited work, which will be used as a reference, is estimating the success likelihood of drastic product/service innovations in terms of the deviations from the commercial offer with regards to the benefits delivered to customers, users and service recipients (whose identification is required as suggested in step *s.*). More specifically, it computes the probability of radical innovations to thrive on the marketplace (named Value Assessment Metrics or briefly *VAM*) according to the diffusion of 12 different modalities in which the occurred transformations take place with respect to reference industrial standards (steps *t.* and *u.*). The 12 variables consist in the combination of three kinds of benefits subjected to transformations and the Four Actions introduced within the Blue Ocean Strategy (Kim and Mauborgne, 2005). The former are articulated in the so called functional features, standing in:

- direct advantages for customers or users (*UF*);
- the attenuation of undesired effects commonly associated with the functioning of the treated system (*HF*);
- the lessening of allocated resources or capabilities required to employ the product under investigation (*RES*).

The latter refer to the introduction of new attributes (*create*), the exclusion or disregard of current competing factors (*eliminate*), the significant growth/decay of performances (*raise*/*reduce*). As a result the combinations apply in each of the following circumstances:

- *UF/create*: a new direct benefit for the customer has been introduced;
- *HF/create*: an undesired effect of drawback, previously not considered in the reference industry, has been firstly treated as a new competing factor;
- *RES/create*: the consumption of an employed resource, previously not considered in the reference industry, has been firstly treated as a new competing factor;
- *UF/raise*: a direct benefit for the customer has been substantially increased;
- *HF/raise*: an undesired effect or drawback results substantially decreased;
- *RES/raise*: the consumption of an employed resource results substantially decreased;
- *UF/reduce*: a direct benefit for the customer has been substantially decreased;
- *HF/reduce*: an undesired effect or drawback results substantially increased;
- *RES/reduce*: the consumption of an employed resource results substantially increased;
- *UF/eliminate*: a direct benefit for the customer is not provided anymore;
- *HF/eliminate*: an undesired effect or drawback, previously considered in the reference industry, results neglected and it is not treated anymore as a competing factor;
- *RES/eliminate*: the consumption of an employed resource, previously considered in the reference industry, results neglected and it is not treated anymore as a competing factor.

The reference proposes to calculate the success probability through two alternative ways, i.e. a formula obtained through a logistic regression model and a computer estimation performed by Artificial Neural Networks. The first option is preferable in order to allow any organization determining the success likelihood of a radical innovation. Success probability scores have to be transformed in terms of *appreciation level*, in order to make the comparison of radical and incremental innovations feasible. The rule to be followed is to assign the value 1 for such a coefficient to those product ideas providing no real competitive advantage with respect to the industrial standard. In the case of radical innovations, such "neutral" situation can be considered for product ideas showing 50% success probability (*VAM*=0,5). By doubling *VAM* index it is then possible to achieve *appreciation level* coefficients that represent positive (negative) effects on competitiveness when holding values greater (minor) than 1.

By exploiting the formulas provided in (Borgianni et al., 2013) the *appreciation level* (α_r) pertaining to radical innovations can be calculated as follows (steps *v.* and *w.*):

$$\alpha_r = 2 \times VAM = 2/(1 + e^{-z}) \qquad (9),$$

with the exponent *z* depending on the quantity of encountered product transformations expressed in terms of pairs constituted by each functional feature and Action:

$$z = -3.19 + 3.44 \times \mathrm{UF/create} + 1.32 \times \mathrm{HF/create} + 2.87 \times \mathrm{RES/create} + 0.97 \times \mathrm{UF/raise} + 1.75 \times \mathrm{HF/raise} + 0.41 \times \mathrm{RES/raise} - 0.84 \times \mathrm{UF/reduce} - 0.27 \times \mathrm{HF/reduce} - 1.78 \times \mathrm{RES/reduce} - 0.46 \times \mathrm{UF/eliminate} + -9.49 \times \mathrm{HF/eliminate} - 1.65 \times \mathrm{RES/eliminate} \qquad (10).$$

3.4 Final computation of the competitive advantage

Because of the lack of information about the relevance of the calculated factors, the authors assigned, in a first instance, an equal weight to the suitability of the innovation in terms of overcoming the current industrial standard (expressed in terms of the variable α) and being proposed in an appropriate situation according to the product evolution (evaluated through π). As a result, the final index through which to undertake decisions about alternative product ideas, i.e. the *advantage* (δ), can be calculated as follows:

$$\delta_x = \pi_x \times \alpha_x \qquad (11),$$

whereas the subscript *x* features the kind of innovation (radical *r* or incremental *i*).

4. Application of the methodology

The methodology shown in Figure 1 was tested through a case study concerning the footwear industry, thanks to the collaboration with two Italian SMEs, which provided data and product ideas to be evaluated. The authors and the enterprises defined a set of potential new product ideas to be assessed, including three radical innovations and an incremental one (step *a.*). The sample comprises personal ideas, product typologies already marketed in other countries, patented inventions or laboratory prototypes which have not been exploited yet to develop commercial items. The following subsections describe the main characteristics of the innovations (to which a perspective commercial name was assigned) and the application of the methodology.

4.1 Proposed innovative product ideas

The ideated new shoes are illustrated in Figure 4, which reports a perspective commercial description of the innovations, their fantasy name and some sketch to help understanding their benefits.

[Figure 4 about here]

The authors and the firms agreed upon the distinction of the product ideas into potential incremental and radical innovations. The former include just the second alternative, which does not present distinguishing new features, but maximizes the flexibility of flat shoes, which is already considered a competing factor in this branch of the footwear industry. As a whole, the product ideas refer to two different industrial standards (steps *b.* and *c.*), standing in common tennis shoes for walking or performing sport activities ("Self-service" and "Vision") and classical flat shoes or ballerinas ("Practical fashion" and "Like I wish!").

4.2 Achieving the pertinence level of the innovations

Patent searches (step *d.*) have to be then carried out for two different typologies of products. The activity was performed by employing the software application Questel Orbit, release 1.8.2 (accessed on October 10th, 2013), thanks to its capabilities to export data, which ease the execution of the following steps. The search strategies were refined in order to obtain the most suitable samples of patents for both the products. The final search criteria were the following:

- sport shoes: Cooperative Patent Classification categories "A43B5/06 OR A43B5/10 OR A43B5/002";
- flat shoes: patents with the words in the title, abstract or independent claims "Flat OR Ballet OR Dolly OR Ballerina", not including the terms "Dance OR Pointe OR Train", belonging to the International Patent Class A43B.

The results were exported and the number of patents was determined for each publication year. The beginning of the evolution cycle (step *e.*) was assigned by identifying the year preceding the first patent. It then resulted that the current product evolution cycle lasts from 1981 for flat shoes and from 1949 for tennis footwear. Subsequently, the *age* was assigned to patents (until 2012, due to the incompleteness of the data about 2013) in both groups with respect to such initial years (step *f.*). Table 1 is an excerpt of the data about sport shoes, exploited to build the diagrams reported in Figure 2.

Year	***Age***	***Age^2***	**Number of patents**
1949	0	0	0
1950	1	1	3
1951	2	4	11
…			
2010	61	3721	4
2011	62	3844	5
2012	63	3969	6

Table 1: structuring the data about the number of patents with respect to year identified as the beginning of product evolution cycle

The data, including also *age^2*, can be employed to perform the multivariate logistic regressions (step *g.*). The software Stata, release 11.0, was used for the purpose of carrying out the operations, which were performed by considering the intercept equal to 0, so to determine just the regression coefficients pertaining to the *age* (*b*) and the *age^2* (*a*), as requested in step *h*. This choice better reflects the shape of the cycle pertaining to the reference model.

The results of the regressions are then reported on Table 2, which includes the determination of *pertinence* indexes. Since the outcomes comply with the requirements posed in the step *i.* by considering 5% confidence as a common rule of thumb, it is possible to calculate *pertinence* coefficients, as indicated in the steps *j.* and *k1*. The relevant results regard π variables (highlighted in Table 2) matching incremental and radical innovations with respect to flat shoes (for "Practical fashion" and "Like I wish!", respectively) and radical innovations with reference to sport footwear (for both "Self-service" and "Vision"). It emerges that at the time of conducting the experiment (year 2013), radical innovations can be favourably designed in the field of flat shoes, whilst the domain of sport footwear faces an opposite condition.

Case	Year of the beginning of the cycle	*Age* coefficient (*b*)	Confidence for *b*	*Age^2* coefficient (*a*)	Confidence for *a*	Years after the pick (*-b/2a*)	Supposed Market Introduction	*age_inn*	*πr*	*πi*
Flat shoes	1981	0,145	0,002	-0,00442	0,018	16	2013	32	0,950	0,050
Tennis and sport shoes	1949	0,191	0,000	-0,00171	0,046	56	2013	64	0,144	0,856

Table 2: regression results and determination of the indexes representing the pertinence levels

4.3 Analysis of the incremental innovation and determination of the appreciation level

The firms allowed identifying 13 customer requirements, which can be valued by the users of flat shoes (step *l.*), and assessing the performances for common ballet pumps (as a reference industrial standard) and the innovation named "Practical fashion" (step *m.*). Actually, just the customer requirement "space limitations" observed a shift in the quality level, as highlighted in Table 2.

All the product features were analyzed by means of a Kano survey (step *n.*), to which 112 respondents participated. The answers allowed determining the pertaining quality attributes for each customer requirement (step *o.*) and the matching *CS*/*DS* indexes, as in step *p.* (3-4). The outcomes can be therefore used to determine the amount of satisfaction generated by the investigated innovation and by the standard, as in step *q.* (5-7), so to consequently calculate the *appreciation level* of "Practical fashion" shoes, as in step *r.* (8). The value of α_i resulted in a score equal to 1.045, as shown in Table 3, which reports all the results leading to the final computation of the variable.

CR	Denomination of the customer requirement	Kano quality attribute	DS_j	CS_j	Performance of the standard p_j	*Sj_std*	Performance of "Practical fashion" p_j	*Sj_i*
CR1	Adaptability of the shoes to the external environment conditions	Indifferent	-0,28	0,50	0,7	0,27	0,7	0,27
CR2	Comfort	Must-be	-0,71	0,38	0,95	0,35	0,95	0,35
CR3	Completeness of the shoes	Must-be	-0,57	0,19	1	0,19	1	0,19
CR4	Manufacturing care	Must-be	-0,71	0,41	0,99	0,40	0,99	0,40
CR5	Cheapness	Attractive	-0,22	0,58	0,9	0,46	0,9	0,46
CR6	Connection with the apparel trends	Indifferent	-0,22	0,34	0,6	0,11	0,6	0,11
CR7	Space limitation	Indifferent	0,00	0,29	0,5	0,15	1	0,29
CR8	Duration of aesthetical characteristics	One-dimensional	-0,77	0,65	0,8	0,37	0,8	0,37
CR9	Mechanical strength of the shoes	Must-be	-0,89	0,43	0,8	0,26	0,8	0,26
CR10	Compliance to a brand	Indifferent	-0,19	0,33	0,75	0,20	0,75	0,20
CR11	Possibility to reuse or recycle the shoes	Indifferent	-0,29	0,47	0,4	0,01	0,4	0,01
CR12	Style, aesthetics	One-dimensional	-0,53	0,70	0,8	0,45	0,8	0,45
CR13	Option for online purchases	Indifferent	-0,13	0,42	0,3	0,04	0,3	0,04
Global satisfaction						3,26		3,40
Appreciation level								1,045

Table 3: outcomes of the Kano survey and indications of products performances to compute the appreciation level for the analyzed incremental innovation

4.4 Investigation of the radical innovations and computation of the appreciation levels

The first activity to be performed when evaluating the potential success of radical innovations is identifying the value transformations occurring with respect to industrial standards (step *s*). In this specific case study, such a task has to be carried out for the innovations named "Self-service", "Vision" and "Like I wish!". The relevant modifications, arisen by benefitting from the cooperation with the firms, are summarized in Table 4, which reports also the classification of the changes in terms of the couples constituted by functional features and Actions (step *t*). The indicated transformations include, besides the benefits described in Subsection 4.1, negative circumstances that are supposed to be met as a consequence of the employment and the envisioned final design of the ideated products.

Product idea	**Transition**	**Classification of the transition**
Self-service	A new feature regards the consistent reduction of movements to lace the shoes	RES/create
	As a new characteristic, chairs or places for sitting are not required anymore to wear the shoes in a comfortable way	RES/create
	The usability of the shoes is substantially increased for visually impaired people	UF/raise
	The usability of the shoes is substantially increased for people with motor handicap	UF/raise
	Due to increased complexity, shoes are supposed to break much more easily	HF/reduce
Vision	A new feature is constituted by the capability to identify obstacles	UF/create
	The usability of the shoes is substantially increased for visually impaired people	UF/raise
	The usability of the shoes in common situations (e.g. when walking) is substantially decreased, because their employment would result awkward	UF/reduce
	As a new emerging disadvantage, the usability of the shoes is jeopardized if auxiliary tools, such as connected headphones, are not employed	RES/eliminate
Like I wish!	A new feature is constituted by the possibility to adjust the height of the heel	UF/create
	The shoes are much more suitable to be worn in certain environments with respect to traditional ballet pumps	UF/raise
	The stability of the shoes is substantially hindered by the new integrated system to raise the heel	HF/reduce
	Due to increased complexity, shoes are supposed to break much more easily	HF/reduce
	The employment of the shoes can result much more complex	RES/reduce
	The integrated system is supposed to substantially worsen the situation with respect to the cheapness of the shoes	RES/reduce

Table 4: value transitions for the examined radical innovations

The performed classification, reported in the last column of Table 4, allows to count the occurrences of said couples (step *u*) and then to compute the supposed success probabilities of the radical innovations and subsequently their *advantage* degrees (steps *v* and *w*). The results of the calculation give rise to the following α_r indexes:

- 1,971 for the innovation named “Self-service”;
- 0,439 for the proposal indicated with the name “Vision”;
- 0,106 for the product idea denominated “Like I wish!”.

As a result, the first product alternative is accounted of the best success chances within the sample of proposed radical innovations.

4.5 Determination of the supposed competitive advantage for all the proposed innovative ideas

Once all the data characterizing the innovations have been obtained, the last step (marked with *x* in Figure 1) consists in computing the *advantage* scores, i.e. the quantitative indexes proposed to support decisions in NPD initiatives. By exploiting the results shown in the previous Subsections, Table 5 illustrates the final outcomes of the procedure (the meaning of the last column will become apparent in the next Subsection).

Innovation	***Pertinence π***	***Appreciation level α***	***Advantage δ***	**Preferences**
Self-service	0,144	1,971	0,284	41

Practical fashion	0,050	1,045	0,052	16
Vision	0,144	0,439	0,063	20
Like I wish!	0,950	0,106	0,101	30

Table 5: final outcomes resulting from the application of the proposed decision support tool

According to the results, the product idea identified with the name "Self-service" shows the best score in terms of potential competitiveness, notwithstanding that radical innovations are expected not to fit the current point of the evolution of sport shoes.

4.6 Verification of the results

Among the individuals participating to the Kano survey, 107 out of 112 expressed their opinion about the product idea they judged as the most appealing after being administered of the descriptions and the sketches reported in Figure 4. The preferences attributed to the four alternatives are reported in the last column of Table 5. At first, it is worth noting that the rankings of *advantage* degrees corresponds to the order of preferences. Besides, the consistency between δ scores and the number of customer choices is remarked by their mutual correlation, since Pearson's coefficient holds a value greater than 0,93.

5. Discussion

A rigorous validation of the experiment would require the introduction of the products in the marketplace and the observation of their real commercial results. Such a task results plainly unfeasible and a roundabout strategy has been followed to evaluate the reasonableness of the results through the activity described in Subsection 4.6. In this sense, the performed test can be considered a preliminary verification of the methodology, allowing to infer whether the original combination of literature evidences is viable to produce reliable results. In other words, the authors carried out the test, consisting in interviewing a sample of consumers, in order to evaluate if the determined δ variables are useful when a firm has to select among a set of product alternatives to be developed.

It might be supposed that the proposed decision support tool is capable to anticipate customers' appreciation towards products, according to the high value of Pearson's correlation coefficient. However, the rigor of the previous assertion and the utility of forecasting customer inclinations towards products are both arguable issues.

With reference to the former, it has to be considered that the main objective of the decision support was the introduction of criteria to take into account dynamic phenomena regarding NPD processes. Whereas the disregard of the *pertinence* factor would have led to completely different (and much worse) results, another test should be performed by considering longer market introduction times and interviewing customers just prior to the launch. Such an experiment would sustain the reliability of the decision support methodology to provide indications for real design cycles, which generally last some years to produce innovative artifacts. In other words, short-term projects would be more easily supported by simple customer interviews rather than examining insightfully product characteristics, performing Kano surveys, investigating patent databases. In this framework, the presented test can be considered just a first step to its validation, also because the involved shoe factories were interested in observing possible trends taking place in their industry, but not really intentioned to shift their production towards the investigated innovations.

For what concerns the latter, it has to be taken into account how initial customer intentions do not necessarily correspond to market results. In this sense, the involvement of customers into NPD activities and decision-making is a risky strategy, although a common practice in the industry (Song et al., 2013b).

Further on, with respect to the resources required to employ the methodology and hence its usability, it has to be underlined that basically two typologies of information have to be obtained outside the firm's know-how: patent data and customer opinions about product attributes. The acquisition of the former is well supported by free online patent databases and tailored software which retrieve and analyze Intellectual Property documents. These data generally suffer from the argued update level of the databases and by the impossibility to gather the contents of unpublished patent applications lying in the secrecy period. The last problem is however not impacting the presented methodology, since it reflects the choice performed by Agarwal (1998) to employ publication years (rather than priority or application dates) to determine the trajectories of products evolution. On the other hand, the delay (besides extremely varying) between the generation of inventions and the publication of patents makes the association of publishing dates with the periods of technological development barely acceptable. The attainment of consumers' inclinations towards product features through Kano surveys is plainly the most onerous activity to employ the methodology. Nevertheless, the task is already accomplished in the practice by many companies also for other purposes and it should not represent, therefore, an insurmountable obstacle to the adoption of the developed decision support methodology.

6. Conclusions and future activities

The present paper describes a novel methodology to support decisions in industry and more specifically to select alternative product ideas on the basis of their supposed market success. The approach, which originally combines findings and quantitative criteria from the literature, attempts to overcome two relevant limitations of existing models to aid decision making. In a first instance, the proposed tool considers the opportunity to develop radical or incremental innovations with respect to acknowledged models of product evolution, envisioning the alternation of moderate

improvements and dramatic changes. Such a kind of transformations is disregarded also in the literature about decision models considering the dynamic effects which severely affect the goodness of NPD tasks. In a second instance, the methodology limits the subjectivity of decision makers, which largely impacts the reliability of diffused multi criteria decision methods. Indeed, any indication provided by experts and even by potential customers regards single product characteristics and it is then marginally influenced by the preferences about product alternatives. In this sense, the methodological objectives posed in Section 2 have been basically achieved.
The investigation of customer tastes with respect to four innovations from the footwear industry has been employed with the objective of verifying the reasonableness of the outcomes, which arose by the application of the methodology. The results show the strong consistence between the coefficients devoted to guide decisions and customers' preferences. Anyway, the limitations of such a kind of test and the difficulties of performing a full validation activity are widely discussed in Section 5.
With regards to the methodological weaknesses of the proposal, it has to be underlined how many inputs are characterized by uncertainty (e.g. the regression coefficients describing product evolution trajectories), possible biases (e.g. the difficulty in identifying overlapping cycles of different product frameworks) and that some steps require ad-hoc measures (e.g. the determination of the relevance of the factors participating to the computation of the *advantage*). The influence of the variability of the inputs has to be primarily assessed in order to undertake measures aimed at making the procedure more robust and the outcomes of the methodology more repeatable. Besides, in order to thoroughly consider the sources of relevant dynamic phenomena discussed in Section 2, the changes pertaining to the importance of customer requirements have to be taken into account in a more evolved version of the method.
In order to ease the application of the methodology and to repeat the test, the authors are available to share the data that are not reported in the paper for the sake of brevity. In addition, they can provide tools to speed up the computation of the variables. Any interested scholar or industrial practitioner can ask the corresponding author the wanted material.

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Figures and matching captions

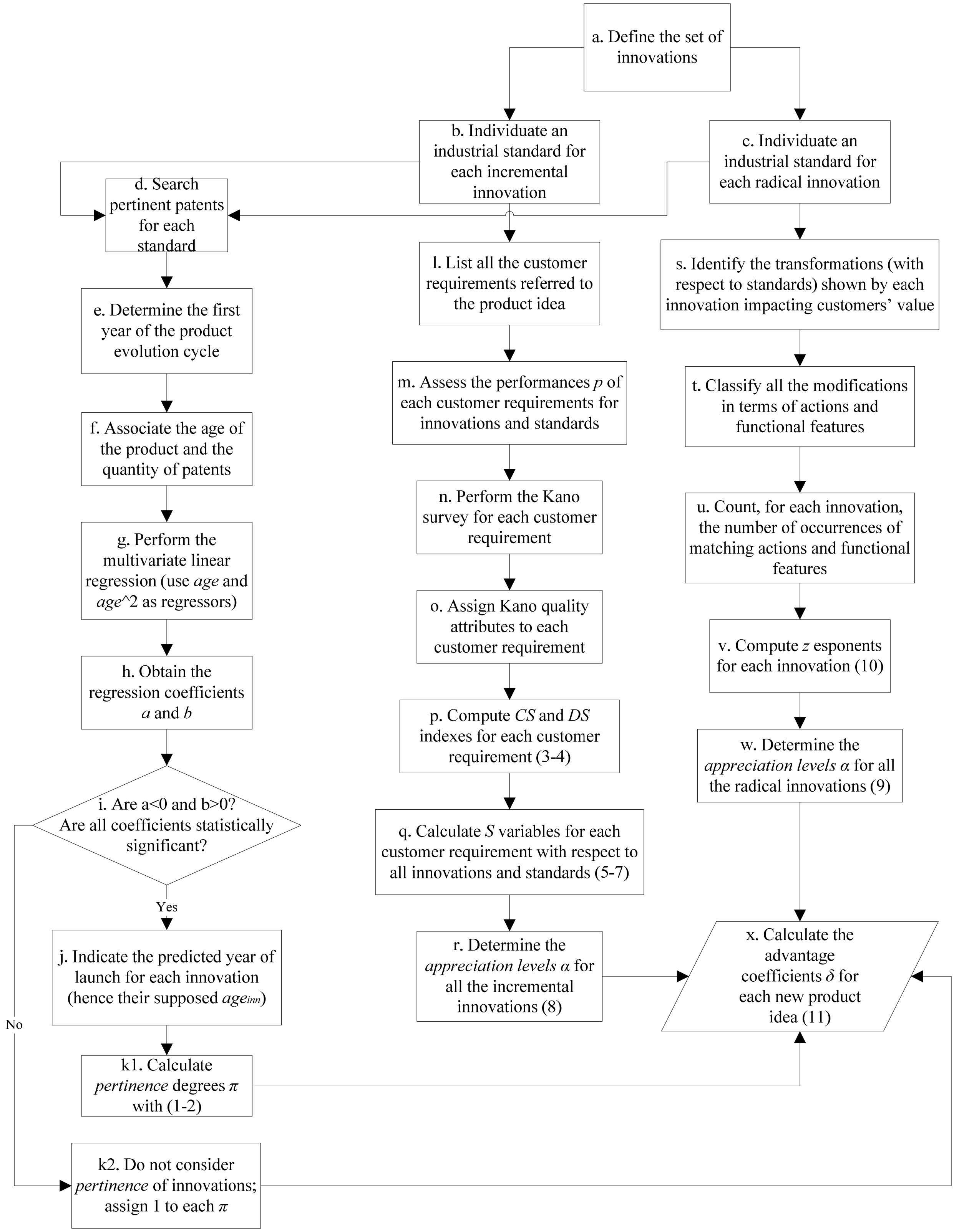


Figure 1: methodological framework of the proposed decision support tool

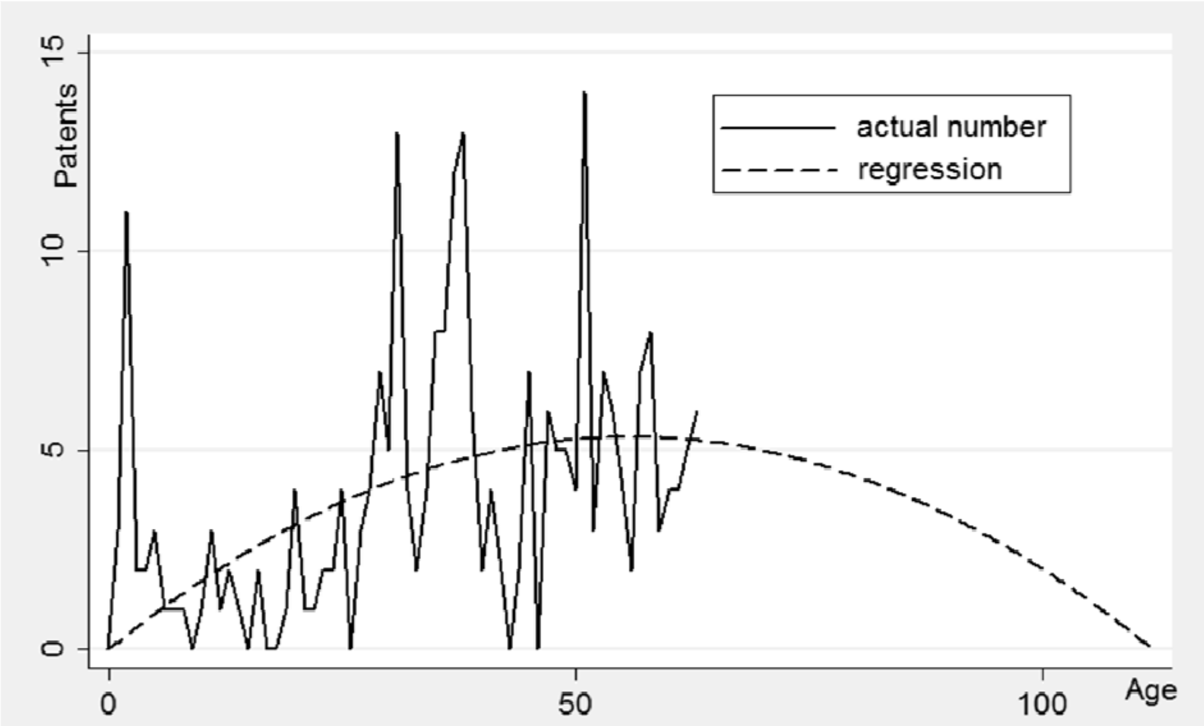


Figure 2: illustrative approximation of the number of patents through a parabolic trajectory

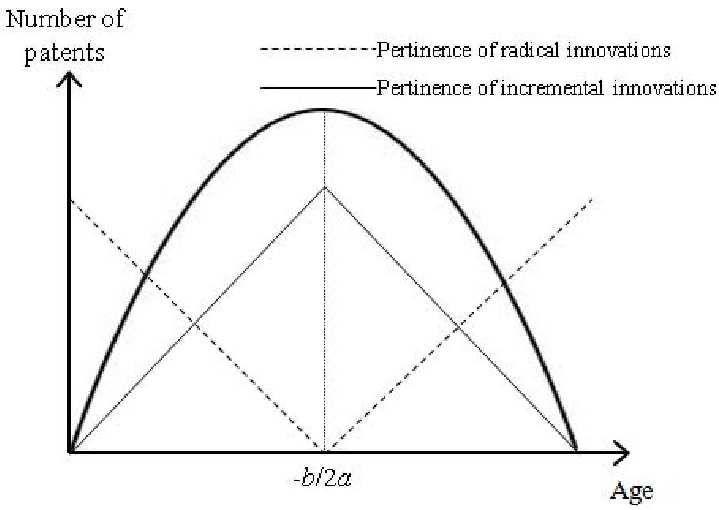
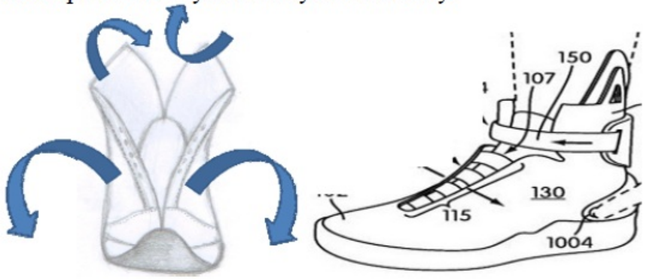


Figure 3: representation of the cycle of product evolution, resulting from approximating the trajectory of the number of pertinent patents, and of the varying pertinence of incremental (continuous line) and radical innovations (dotted line)

Option A “Self-service”
Are you tired of bending down when wearing the shoes? Do you need to do it frequently and you don’t have room for sitting? Is the dressing room of the gym crowded and can’t you move easily? The problem is nowadays solved, because the new tennis shoes “Self-service” get worn by themselves, without bending down or using the hands. Thanks to a twofold mechanism, the shoe gets closed and latched. The solution is of course tailored to the elder people, individuals with motor handicaps and to anyone always in the hurry!



Option B “Practical fashion”
Each time you go away, even for few days, suitcases and luggage compartments full of shoes are you concern. Why not to save room by adopting the low shoes “Practical fashion”? They are completely foldable and do not forgo the adherence to fashion trends. Bring them with you in your purse or backpack! Their extreme flexibility allows besides a very comfortable fit: your feet will thank you!

Option C “Vision”
How many times did you slip on stairs or little obstacles you didn’t notice? Are you delivering bulky items that don’t let you see the stairs? Are your relatives or friends with motor handicap give up walking outside, because they are afraid to fall down? Perhaps you haven’t ever thought that nobody can see better than your own shoes. “Vision” developers did. The adopted technology communicates whoever wears these shoes when obstacles are present or the track is free. Any headphone is enough for the scope!

Option D “Like I wish!”
Do you wear comfortable ballerinas with pleasure, but the people say they are not sexy and do not fit formal environments? Never fear! Today it is possible to have more shoes in one, thanks to the footwear line “Like I wish!”. They stand in common shoes whose heel height is completely adjustable. Fashion takes 1000 forms and 1000 heights!

Figure 4: description of the alternative product ideas pertaining to the footwear industry