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New product development assessment: towards a normative-contingent audit

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Abstract

Purpose – A large amount of research deals with the identification of management practices related to new product development (NPD) success. To this purpose, assessment tools capable of helping enterprises to set up improvement processes are of extreme importance. The aim of this paper is to build a product development assessment model based upon a normative-contingent approach.

Design/methodology/approach – First, a literature review of the main approaches and models used in NPD assessment was carried out. Second, the tool was tested in five firms. The case studies allowed the authors to test the tool in its prototypal phase in order to assess both its limits and potential and also to highlight possible improvements.

Findings – The assessment tool developed yields a clear understanding of the current state of product development process in an organization in order to facilitate a shared understanding of the weakness and deficiencies, to enable effective process management, to develop implementation plan to support change initiatives and to support process improvement using metrics.

Originality/value – The product development assessment model is based upon a normative-contingent approach meaning that the prescriptive requirements are defined according to the logic of coherence: requirements vary in relation to contextual conditions. In particular, there are two important context factors which are considered to have a significant influence on NPD process: the complexity of the product-market interface and the enterprise's NPD strategic orientations.

Keywords Product design, Critical success factors, Organizational performance, New products, Product development

Paper type Research paper

1. The role of assessment in supporting the evolution of new product development process

The product development activities from idea generation to market launch greatly influence the enterprise's innovative performances (Clark and Fujimoto, 1991; Griffin, 1997). The design of new product development (NPD) process has strongly evolved and, throughout the years, various models have gradually emerged.

The first generation of these models, which prevailed up to the 1980s, are the so-called sequential models in which the various process phases are conducted in a strictly sequential discipline in order to simplify and rationalize a basically complex activity such as product innovation.

In the attempt to overcome certain limits set by sequential models, especially those connected to the sequential order of phases, during the first half of the 1990s, on the wave of the experience gained by Japanese enterprises, the concurrent engineering (CE) approach was proposed. With this approach, the process is considered as a series

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of phases carried out in parallel, that is with more or less-overlapping tasks, or in more radical cases, carried out simultaneously.

Both approaches present a common trait: they are characterized by the management of single development processes, i.e. the potentially existing relations among on-going projects are not explicitly considered. However, the need to reformulate project portfolio strategies has arisen owing to the increasing levels of complexity which characterized the competitive scenario. In particular, high-variety production like mass customization requires that what were once considered as autonomous and independent projects, competing for the attainment of resources, now belong to a technological trajectory that enhances interdependence bonds and relations according to a multi-project perspective.

This evolution of the NPD process means that manufacturing firms are facing up to the challenge of implementing new approaches and working methods. As a result, the challenges and demands on the NPD process is under-renewed pressure to deliver product efficiently in faster time-scales and at higher launch quality levels.

There is a considerable body of literature which seeks to identify the ingredients for successful NPD and various methods have been developed in order to improve process efficiency and overall NPD effectiveness (Booz *et al.*, 1982; Link, 1987; Cooper, 1990; Griffin and Page, 1993; Pittiglio and McGrath, 1995; Griffin, 1997). Assessment tools have proven to be effective in providing organizations with a systematic and regular measurement system ensuring that any approaches incorporate high levels of quality practice aimed at achieving excellence (Rosenthal, 1991; Page, 1993; CERC, 1993; De Graaf, 1996). These studies belong to a wider literature that has drawn enterprises' attention to the key role of organizational assessment as an important tool for continuous improvement.

However, current research and literature on assessment tools within NPD present one drawback: the majority of the studies have developed tools which adopt "excellence models" as evaluation frameworks for assessment process. This has contributed to the spread of a specific form of assessment logic which is basically a complex search for conformity (with reference to clearly defined judgement dimensions) to a set of non-prescriptive requirements which reflect leading-edge practices (deemed to be universally valid) for achieving performance excellence.

While the search for conformity is the dominant evaluation logic in these tools, the opinion of the author is that an assessment tool for NPD process should be based on a normative-situational or normative-contingent approach. In other words, the prescriptive requirements must be defined according to a contingency approach based upon the logic of coherence: requirements vary in relation to contextual conditions. As we will highlight in the following sections, this approach practically does not appear in the models and tools available today. Notwithstanding, several NPD success factor studies conclude that success is contingent on the creation of superior, clearly differentiated, unique, and "well-designed" products (Cooper, 1994; Page, 1993; Ernst, 2002).

The objective of this paper is to illustrate the development of a prototype assessment tool that yields a clear understanding of the current state of product development process in an organization in order to facilitate a shared understanding of the weakness and deficiencies, to enable effective process management, to develop implementation plan to support change initiatives and to support process improvement using metrics.

The rest of the paper is organized as follows. In Section 2, we will analyse and classify the main approaches used in NPD assessment and the main assessment models currently available. Section 3 describes the general architecture of the proposed assessment tool, while a detailed description of the tool is reported in Section 4. In Section 5, various distinguishing features of the proposed model implementation, which emerged during the model testing, are illustrated.

2. Approaches to NPD assessment: a classification

There is a large amount of research identifying management practices related to NPD success (Adams-Bigelow, 2004; Cooper *et al.*, 2004a, b, c; for a synthesis, see Griffin, 1997). Kahn *et al.* (2006), in the introduction to the dialogue on best practices that appeared in the *Journal of Product Innovation Management*, point out the prime importance played by audit tools that help enterprises identify the level of complexity of adopted practices, compare themselves with other enterprises and/or with currently identified best practices and set up improvement plans.

It is no surprise, therefore, if in the past years a large number of assessment models for product innovation management (PIM) have been proposed and if renowned academic reviews have appreciated studies dedicated to audit tools (Chiesa *et al.*, 1996).

A strict analysis of the various models and tools available points out how the majority of these methods are not really capable of effectively supporting company assessment needs since they do not envisage clear mechanisms for stimulating critical considerations on current management practices and for sustaining improvement planning. In order to understand the fundamental features of the various assessment models proposed in the literature and to highlight the main differences, it is useful to take advantage of the matrix shown in Figure 1, which represents a refinement of the framework initially developed by one of the authors (Biazzo and Bernardi, 2003) for analysing the different perspectives on organizational self-assessment coming from quality awards models and the organizational studies tradition.

The matrix differentiates the assessment methods on the basis of two fundamental dimensions:

(1) A first dimension regarding the logic of assessment adopted: conformity (assessment of adherence to a set of requirements); coherence (assessment of practices alignment with respect to the application context); causality (the use of

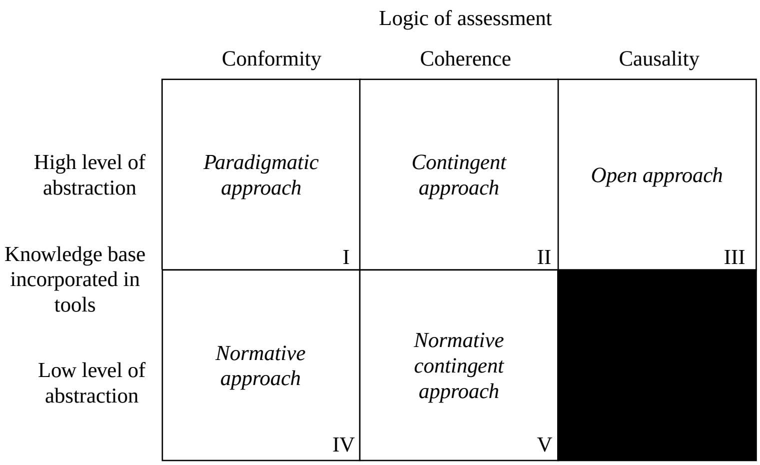

Figure 1.
Approaches to management practice assessment: a classification

diagnostic schemes that impose and support explicit modelling of cause-effect relations between ineffectiveness and inefficiency symptoms observed in the system and factors generating these symptoms). It is the case to point out that the causality hypothesis also exists in the logic of conformity and of coherence, although implicitly: conformity implicitly assumes a positive relation between adherence to a model and "good performances"; coherence implicitly assumes a positive relation between practice-context alignment and "good organizational performances". What distinguishes the causal approach is the search for an explicit modelling of the cause-effect relation.

(2) A second dimension focusing attention on the nature of the tools used with reference to the level of incorporation of diagnostic expertise. The tools feature high levels of abstraction when they provide guidelines and general principles that, although orienting and supporting assessment, are not able to fully substitute the judgment skills of single evaluators; in the case of low levels of abstraction, instead, the tools contain operational and detailed indications that reduce assessment subjectivity.

By intersecting the two dimensions, five different diagnostic approaches may be identified; Cell VI is conceptually empty as it represents a diagnostic approach based on tools that should contain a codified body of knowledge concerning the aetiology of organizational problems, and hence enable analysts to quickly identify the sources of the ineffectiveness underneath observed problems. Developing these tools is hindered by the enormous complexity and chaotic nature of human systems (Thiétart and Forgues, 1995) – which has led many scholars to highlight the severe limitations of establishing invariant laws for social phenomena (Numagami, 1998) – and by the non-cumulative nature of organizational studies, which is tied to the incommensurability of the different ontological, epistemological and methodological assumptions that underpin research practice (Astley, 1985; Burrell and Morgan, 1979; Jackson and Carter, 1991).

In the paradigmatic approach (Cell I), assessment is guided by a model which requires compliance with a set of non-prescriptive requirements; this approach is called "paradigmatic" because this kind of model can be conceptualised as a "paradigm", i.e. "a management system that is not a collection of techniques, methods and approaches, but rather a coherent body of inter-dependent criteria and logic in the spheres of organization, management, decision making and motivation". The search for compliance with the criteria of excellence models – such as the European Foundation for Quality Management Excellence Model or the Malcolm Baldrige Criteria for Performance Excellence Framework – is the most known and diffused paradigmatic approach to assessment.

In the normative approach (Cell IV), assessment is based upon the determination of the level of adherence to a set of prescriptive requirements which, on the whole, delineate a non-situational operational model. The International Quality Rating System, which was developed by Det Norske Veritas, is an enlightening example. Quality management requirements have been translated into a complex questionnaire with 810 items "IQRS is designed as an objective tool for measuring Quality Management performance [...]. There are very few items requiring 'professional judgement' by the auditors [...]. Indeed, there is only one standard interpretation for the requirements laid out in the IQRS questions". This tool contains clear judgement criteria because the self-assessment questionnaire is almost completely made up of highly detailed yes/no questions.

In the normative-contingent approach (Cell V), prescriptive requirements are situation-specific and they are inserted in assessment tools. Burton and Obel's (1998) OrgCon® expert system for organizational structure design is an example of this diagnostic approach. OrgCon® (Organizational Consultant) is a "decision-making support tool that can help managers, scholars and consultants to assess organisational problems and to recommend changes" (Burton and Obel, 1998, p. 11). The knowledge base of this tool consist of a hefty set of "if-then" organizational design rules (i.e. "if A is a fact, then do D"), which is the result of a complex combination of the different contingency theories developed within organization theory literature.

Cell II contains the contingent approach to assessment, which is based on frameworks that act as guidelines for analysing relations between contingency factors and organizational attributes, but do not contain detailed judgement criteria. In the field of organizational analysis, examples may be found in the famous 7-S model (Bradach, 1996) or in Galbraith's "star model" (2002). Finally, the open approaches (Cell III) use tools that frame the analysis of cause-effect relationships, such as Porras' (1987) "stream organizational model": this model requires the construction of a diagram (stream diagnostic chart) that traces the connections between ineffectiveness symptoms and problems underpinning such symptoms.

Mapping the most relevant NPD assessment tools onto the matrix of Figure 1 allows the creation of the classification diagram shown in Figure 2.

Capability Maturity Model Integration (Software Engineering Institute, 2001) models are well representative of the paradigmatic approach to NPD assessment: they prescribe a set of objectives that the organization must pursue in order to excel in product development and they describe the management practices typically associated to the achievement of objectives, without, however, requiring implementation as described in the model: each enterprise is invited to adopt the solutions best responding to the specific context it is operating in. Opinions on the quality of the practices adopted, that is, adherence to the reference paradigm, are formulated (as in excellence models of quality awards) by expert assessors. The methodologies proposed by Tennant and Roberts (2003) – new product introduction self-assessment – by Cormican and O'Sullivan (2004) – PIM scorecard and by Van Landegem and De Wilde (1994) – simultaneous engineering gap analysis (SEGAPAN) also follow a paradigmatic approach.

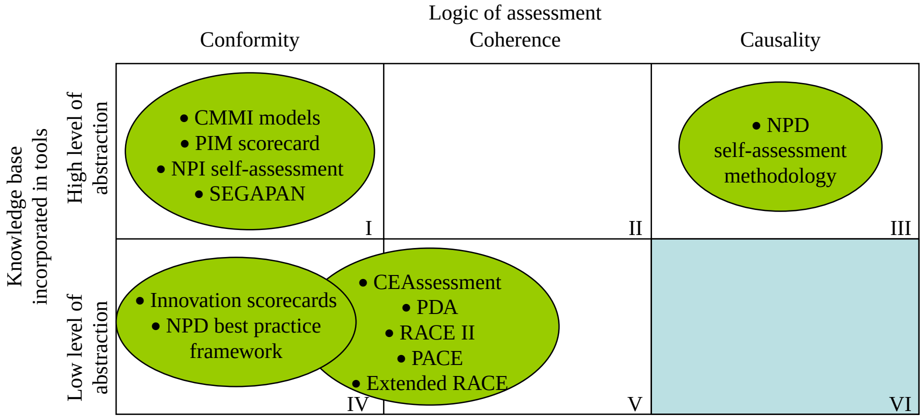

Figure 2.
Approaches to NPD assessment: a classification

An example of normative audit is provided by the innovation scorecard of Chiesa *et al.* (1996). The audit is structured in 23 assessment practices: a scale (called "maturity grid") has been developed for each practice describing four distinct levels of complexity (from elementary to best practices); a similar approach was taken up by Kahn *et al.* (2006) when creating the "NPD Best Practice Framework".

An interesting attempt to offer an assessment tool that is close to the normative-contingent approach cell is represented by the product development best practices and assessment (PDA) of DRM Associates (2001). The PDA is made up of 269 "best practice" descriptions grouped into 28 categories. For each best practice filling in the PDA, it is necessary to make a double assessment: on the one hand, to establish the importance of the single practice for the enterprise and, on the other, the level at which it is implemented. Furthermore, the enterprise needs to assign an importance score to each category. The tool, therefore, tends to give a "personalised" assessment of practices with respect to the context in which the enterprise operates. The PDA, however, is only partially normative-contingent because the "personalization" of the ideal profile (through the assignment of importance given to both single best practices and to categories) is left to the evaluator's subjective judgement: no knowledge related to relationships of coherence between practices and firm's situation is included in the proposed tool. A similar "subjective" personalisation of the expected maturity levels of product development practices distinguishes the design audit tool by Moultrie *et al.* (2007), the CE assessment of Carter and Baker (1992), the readiness assessment for CE (RACE II; De Graaf, 1996), the practical approach to CE developed within a Brite project funded by the European Union (Pawar and Thoben, 1995) and, finally, the extended RACE tool elaborated by the Swedish Institute for Systems Development.

Finally, an example of causal approach in the assessment of product development effectiveness conditions may be found in the NPD self-assessment methodology by McQuater *et al.* (1998): the authors suggest that the self-assessment process should start by identifying the symptoms revealing the ineffectiveness of product development activity and should then individuate the causes by creating classic cause-effect diagrams supported by a generic model summarizing the possible areas of inquiry.

3. A normative-contingent NPD approach

The study of the main approaches and models used in NPD assessment has revealed the lack of a tool featuring a real contingency approach based upon the logic of coherence, namely, where requirements vary in relation to the contextual conditions that are internal and external to the organization. Since the purpose of this work is to identify the fundamental features of an appropriate assessment methodology for supporting NPD in manufacturing enterprises, it is advisable to critically consider the various approaches that could be employed.

Assessment inspired by a paradigmatic approach presents aspects of undoubted interest and value; this diagnostic procedure, based upon formal rationalization, represents an important chance to generate an interaction context among users who may share and articulate their knowledge through dialogue and reflection. Since no assessment parameters have been included in the supporting tools, it is evident that the assessment quality strongly depends on the evaluators' experience and skills; this aspect considerably limits the use of the paradigmatic approach and this is particularly true in small and medium enterprises (SMEs), due to the "marginalization of good design practices" that characterize many small companies (Moultrie *et al.*, 2007).

In the open and contingent approach, the problem related to the analysts' level of experience and expertise is even more critical since the tools are realized with general analysis diagrams which do not include coherence assessment criteria and which, in the case of the open approach, do not offer hypothetical "knowledge archives" for reconstructing the links between the perceived symptoms of ineffectiveness and the underlying causes.

The normative approach instead, in terms of level of dependence from the evaluators' skills, appears to be particularly suitable for organizations. This approach, however, could present some limitations: the normative specification of "excellent" practices establishes a non-situational operational model as a reference scheme and risks promoting organizational and management solutions that might not be suitable to the "situation" or to the context in which they are used.

These considerations lead to believe that the normative-contingent approach could offer a correct and appropriate orientation towards the definition of assessment methods and tools for enterprises. The general architecture of the proposed normative-contingent NPD assessment tool is shown in Figure 3. A detailed description of the tool is given in the following section, however, for a better understanding of the tool itself, the following five aspects are here emphasized:

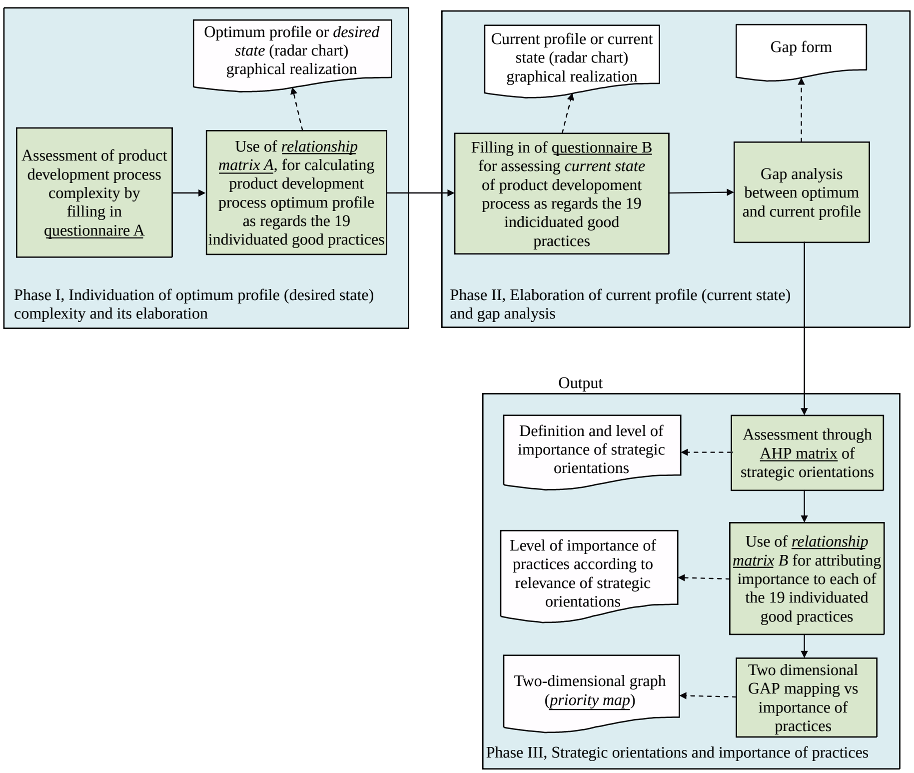

Figure 3.
Architecture of NPD assessment tool

(1) Product development process assessment is performed by evaluating company according to 19 assessment dimensions; the dimensions describe the set of "best practices" that characterise the process in terms of methodologies, techniques, tools, and organizational choices.
(2) The tool elaborates two profiles called desired state (TO-BE) and current state (AS-IS) and emphasizes any existing gap for which suitable improvement programmes are envisaged.
(3) The desired state is identified in Phase I (Figure 3) following a contingent approach: in order to identify the ideal positioning, the tool evaluates the alignment of practices with respect to the product-market complexity (defined through the Questionnaire A).
(4) The current state is elaborated in Phase II (Figure 3). In this phase, the gap analysis between the two profiles is also carried out. The current state is defined by examining the practices actually carried out in the enterprise compared to those envisaged by the 19 assessment dimensions for the product development process.
(5) The proposed tool also presents a second moment of contingency, precisely in Phase III (Figure 3), when a level of importance is assigned to each of the 19 assessment best practices depending on the coherence displayed by the practice to sustain the enterprise's innovative strategic orientations. In other words, the enterprise's NPD strategic orientations are considered important context factors capable of strongly conditioning the level of adoption and implementation of different practices, and also their importance. A detailed description of the assessment tool is given in the following section.

4. The product development process assessment tool

In order to build a tool for the assessment of the product development process, the elements or dimensions distinguishing such process needed to be firstly defined, in other words, we had to identify exactly what the tool had to measure. To this end, a literature review was conducted using a systematic approach (Tranfield *et al.*, 2003) to establish the current knowledge influencing the NPD assessment. In order to identify the relevant papers specific management databases, such as Business Source Premier, Web of Knowledge, Emerald Insight, Management and Organization Studies, ABI Inform, and Science Direct, were searched. Relevant papers were identified after a review of abstracts followed by full text reviews. The selected papers were analysed and integrated with key books on the areas of interest. To recognize the key NPD best practices an initial starting point that was of great help, was the comparative analysis of the previously mentioned main assessment models of product innovation practices (Figure 4). All these models were built after an in-depth literature review or/and empirical investigations, consequently, they still incorporate and synthesized the knowledge available about NPD best practices of assessment tools.

As shown in Figure 4, the NPD assessment model proposed in the literature are generally organized on a two-level architecture: at the first level, we find the so-called major dimensions while the key factors (or best practices) constituting these dimensions are positioned on the second level.

Figure 4.
Major dimensions and key factors of the main NPD assessment tools

In order to complete the investigation, we conducted a second analysis of the studies identifying managerial practices connected to NPD success to identify specific strategy, organizational, process, methodology, and technology issues to address as part of a high performance NPD process.

In addition to the studies carried out by Adams-Bigelow (2004), Cooper *et al.* (2004a, b, c) and Griffin (1997), research conducted by Arthur D. Little (1991), Kuczmarski & Associates (1994), Montoya-Weiss and Calantone (1994), Pittiglio and McGrath (1995), Eisenhardt and Tabrizi (1995) was of precious aid.

Three goals characterising a high performance NPD process were identified. First of all, in order to be successful the NPD process must be strongly oriented to the market. It is important to clear understand customer requirements which must guide all the development activities according to a perspective of effectiveness. At the same time, the NPD process uses resources to transform inputs into outputs and it is of paramount importance to manage such a process in a cost efficient way. Third, it is widely known that a high level of integration and collaboration between NPD and manufacturing is critical for success (this partnership must involved the suppliers too).

Merging the main dimensions of the NPD assessment tools with the managerial practices connected to NPD success investigated by literature, we identified 19 best practices as fundamental in NPD management. These practices are critical in supporting the attainment of the three above-mentioned goals so as to operate with a high performance NPD process.

A total of six practices are investigated to assess if the product development process is customer-driven "market orientation":

(1) a clear and shared definition of company strategy and NPD;
(2) adequate planning and control of product range plan;
(3) the use of appropriate methods for understanding customer needs;
(4) the use of appropriate methods for correctly elaborating customer needs in order to achieve precise product specifications;
(5) a new product launch and commercialization process coordinated with all different relevant company functional areas; and
(6) attention towards environmental problems.

The ability to operate with a product development process that is strongly integrated with industrialization activities and more in general with production activities "production integration" – the latter to be considered in terms of a system extended to suppliers – is measured through the following seven key points:

(1) The degree of production personnel involvement in the project team.
(2) The capability to accurately define cost and investment objectives.
(3) The use of design for manufacturing (DFM) and design for assembly (DFA) methods.
(4) The level of integration of suppliers/sub-suppliers in product development activities.
(5) The adoption of structured methodologies aiming at ensuring robust product design.

(6) The presence of formal plans and schedules developed for transitioning new products into production and ramping up production.

(7) The employment of computer-based tools to support an integrated management of design and manufacturing data.

Finally, working in an organized manner with a rational and efficient use of resources is assessed by examining the following six factors "process management":

(1) The presence of an "environment" orientating and stimulating personnel towards continuous improvement and favouring creativity.

(2) The role of management in supporting NPD activities recognized as being crucial for the enterprise's competitive success.

(3) The use of project management methodologies for planning and organizing work.

(4) The existence of an NPD procedure that clearly defines tasks, responsibilities, activities to be performed, information flows, and performances.

(5) The regular use of project teams with definition of roles, responsibilities and relations between team and company organization structure.

(6) The use of computer-based tools supporting designers' activities and for technical product data management.

The resulting architecture of the NPD assessment tool proposed is shown in Figure 5.

For each of the 19 best practices, a four-level maturity scale or "maturity grid" has been developed: the scale aims at identifying four distinct levels of complexity from elementary to an integrated and complete approach. In Table I, an example of scale used in the tool is reported.

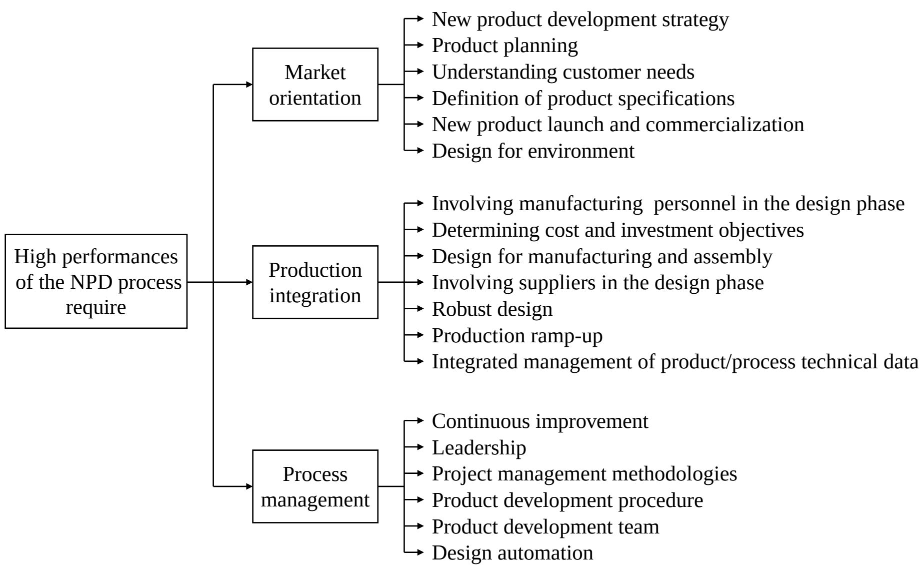

Figure 5.
NPD best practices of our assessment tool

Level	Level description
1	We work with many suppliers which compete against each other and with which we have conflictual relationships. They are not involved in the development process
2	A number of suppliers have been identified with which we exchange information during the development process in order to identify in advance product constraints and improvement opportunities
3	We have set up a supply reduction and selection policy in order to establish more collaborative long-lasting relationships. Starting from the early development process phases, we involve critical suppliers/sub- suppliers and we highly consider their suggestions and considerations
4	We work with a restricted number of suppliers, which are strictly selected, continuously assessed and totally integrated. We regularly provide them with training and technical assistance services. They are highly committed to our product development activities, they take part in project group activities and have qualified project abilities which enable them to give important contributions in terms of material selection, prototype development components reduction and standardization, etc. These relationships strongly influence our ability to contain quality problems and production costs and to shorten time-to-market

Note: Production integration; practice: involving suppliers in the design phase

Table I.
An example of scale used by the assessment tool

After having described the structure of the tool, we turn now our attention to the assessment logic. The discussion will be carried out examining separately the three main phases.

Phase I – elaboration of the desired state

As previously stated, the assessment tool makes a double assessment: on the one hand, to establish the importance of the single practice for the enterprise and, on the other, the level at which it is implemented. In doing this, two distinct profiles are elaborated called, respectively, desired state and current state. They are subsequently compared in order to determine gaps or critical areas which require the setting up of appropriate intervention actions.

The problem at this point is how to individuate the desired state, in other words, how to determine the optimum positioning level for each 19 best practices. The optimum positioning is of a contingent nature and we think that it depends on product-market complexity. In this sense, an interesting diagram that analyses the level of product-market complexity was developed by Clark and Fujimoto (1991) who distinguish between complexity of product (internal) structure and complexity of market interface. Internal structure complexity refers to the number of components and production phases needed for their realization, to the number of different component interfaces, to technological complexity, to the need to involve suppliers in the development process, etc. Market interface complexity refers to the number of performance criteria that should be evaluated for choosing the product, to the importance of ambiguous and subjective assessment dimensions with respect to the measurable and objective dimensions, to the variety of markets catered for, etc.

In addition to the already mentioned diagram of Clark and Fujimoto, the Market Turbulence Map Instrument developed by Pine (1992) was of particular help.

Product-market complexity is measured through Questionnaire A; the questionnaire is made up of 32 statements and an evaluation for each statement is requested.

The degree of agreement or disagreement with the sentence is expressed with a mark from 1 to 10, where one indicates maximum disagreement and ten maximum agreement (see Table II where a part of Questionnaire A is reported).

By using a matrix similar to the relationship matrix of the house of quality of the quality function deployment (QFD) methodology (Akao, 1990), the answers to the 32 questions of Questionnaire A are crossed with the previously mentioned 19 practices in order to assign each of the latter with an optimum level (on a one to four scale) and identify, therefore, the desired state. More specifically, in order to identify the desired state profile, a 32×19 matrix was built assigning a correlation coefficient (0, 1, 3, 9) at each row-column intersection. A high coefficient value underlines the importance of the practice of the ith column in relation to the content of the question of the jth row: for example, with reference to the "use of appropriate methods for understanding client needs" practice, this coefficient will have a higher value in correspondence with the statement of questionnaire A "Our clients are distributed over various geographical areas featuring different needs/demands to be met, regulations to be respected, cultural and social values, finishing levels requested". In order to calculate, for each practice, the optimum level upon which one should be positioned, we employed the so-called independent scoring method (Cohen, 1995): the row value assigned at the questionnaire A statement is multiplied by the corresponding column correlation coefficient and the 32 resulting values are therefore added up and normalized in the one to four interval, thus obtaining the level sought for.

The optimum level (L) of each practice is calculated using the following formula:

$$\frac{L_i = \sum_{h=1}^{32} R_h^* d_{ih}}{\sum_{h=1}^{32} d_{ih}}$$

where:

$$i = 1, \ldots, 19;$$
$$h = 1, \ldots, 32;$$

Mark with a score from 1 to 10 how much you agree with the following statements

1. Our product range has been continuously expanding over the past years
2. We are well aware of customer needs during new product development
3. We are not well aware of the features/functions of technologies employed during new product development
4. Our customers are located in various geographical areas featuring different needs/demands, regulations to be respected , cultural and social values, finishing levels required
5. Our products satisfy many different customer needs
6. Our products are purchased by industrial customers who use them in their production processes
7. Our products are made of many components/modules that are interconnected by a large number of different interfaces
8. Our products feature a clear modular architecture
9. The finishing and precision level required (tolerances, assembly, material quality, etc) when developing our products is high
10. Our sector features a large number of competitors presenting strong product differentiation
11. Competition in our sector is particularly harsh and is based on performances such as product innovation and services

Notes: 1 – completely disagree; 10 – completely agree

Table II. Questionaire A for evaluating product-market complexity

L_i = optimum level for each practice *h;*

R_h = score of the Questionnaire A; and

d_{ih} = correlation factors.

It should be noted that unlike many models found in literature which individuate just one expected complexity level for all product development practices, in this tool it is possible to define the relative ideal level for each single practice and, therefore, to have greater analysis sensitivity.

Phase II – elaboration of the current state

In this phase of the assessment process, the current state is elaborated by providing the working group with Questionnaire B, composed of 19 best practices and the related four-level maturity scales. To establish the level at which each single practice is implemented, it is necessary to choose the level whose description better describe what is actually performed in the enterprise. It is important to be as objective as possible, to work carefully and scrupulously and to try not to overestimate or underestimate company activities. By comparing the desired state with the current state, the previously mentioned gaps arise (Figure 6).

Phase III – assessment of strategic orientations and priority map creation

The gap analysis between desired state and current state points out improvement areas. However, the issue of which sequences of improvement initiatives, the company must undertake to improve its performances within NPD still needs to be defined. As made by various models presented in literature, practices presenting a larger gap could be

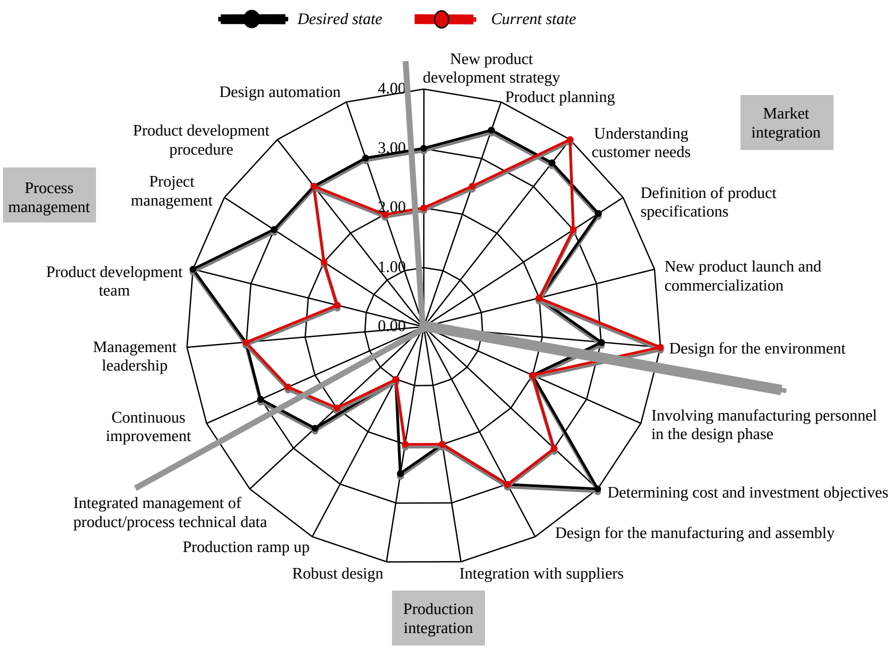

Figure 6.
Desire state vs current state: an example

tackled first. Our tool works in a different way since it introduces here a second level of contingency. As already underlined, we believe that the strategic choices that guide product development activities are key situational factors capable of deeply influencing the relevance of various product development practices. As a result, four strategic orientations were firstly individuated and may be summarized as follows (Ho, 1993):

(1) *Time to market*. In this case, the speed with which new products are introduced on the market, compared to competitors, is privileged.

(2) *Product cost*. The aim here is to develop low cost product according to a cost leadership strategy (Porter, 1980).

(3) *Performance/technology*. The focus is on maximizing product performances through the continuous use of innovative technologies.

(4) *Quality/reliability*. Close attention is paid to offer solid and consistently good in quality products.

In order to understand the choices made by a firm in terms of innovation strategy, the well-known multi-criteria decision-making method called Analytic Hierarchy Process proposed by Saaty (1980) was employed. Using this method, it is possible to suitably rank the different strategic orientations.

A second relationship matrix is then used with rows containing the four strategic orientations and relative degree of importance coming from the previous analytical hierarchy process matrix, and with columns coinciding with the usual 19 best practices. In this case, the correlation coefficient means how much a specific practice is coherent with a certain strategic orientation (for example, the "robust design" practice plays a vital role when the enterprise intends competing by leveraging high quality/reliable products). By carrying out a procedure similar to the one previously mentioned, the importance of each single practice is individuated according to the importance taken on by the four strategic orientations.

The last step of the assessment process regards the construction of the priority map. Having defined first the gap between the desired state and current state of each best practice and then the importance of each practice in relation to the strategic orientations expressed by the enterprise, a two-dimensional mapping of the practices may be performed on the gap size – importance Cartesian plan. The practices contained in the upper right area of the graph feature both a large-sized gap and strong importance; they present the highest level of criticality and therefore are the first that must be addressed (Figure 7).

5. Concluding remarks

The present study proposes an NPD process assessment method employing a normative-contingent approach, based upon the logic of coherence. The proposed method is suitable for effectively supporting assessment needs thanks to the presence of mechanisms capable of stimulating critical thinking towards current and best management practices; these mechanisms support the definition of priority maps and guide suitable improvement interventions.

The prototype tool has been tested in five enterprises:

(1) *Alfa*. A small-sized manufacturer of bread-making equipment.

(2) *Beta*. A medium-large sized enterprise producing cooking equipment for the catering industry.

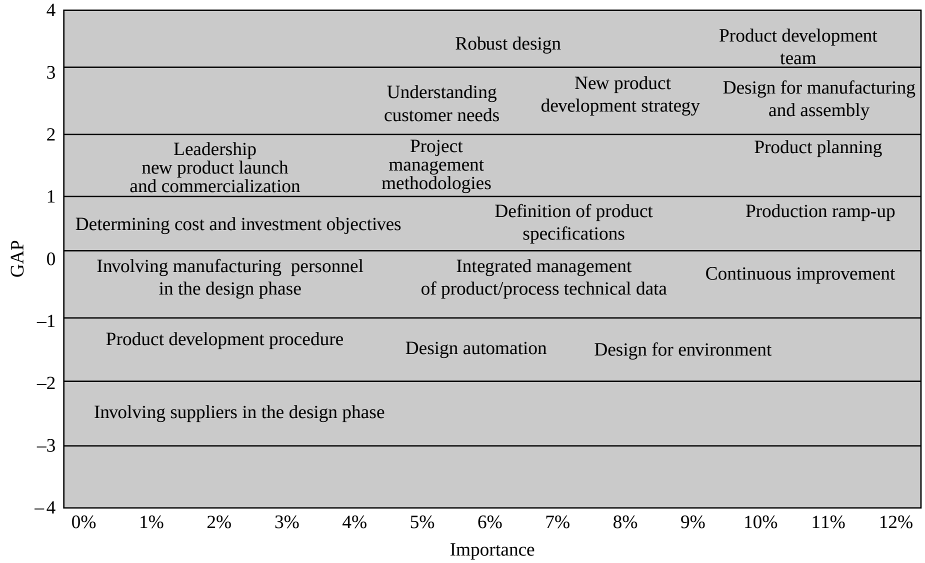

Figure 7.
An example of priority map

(3) *Gamma*. A medium-sized enterprise which design and produce payment systems for the automatic distribution industry.
(4) *Delta*. A medium-sized manufacturer of wood and panel processing machines.
(5) *Sigma*. A small-sized enterprise operating in the leather-finishing machines industry.

The case studies carried out allowed us to test the tool in its prototypal phase in order to assess both its limits and potential and also to highlight possible improvements. Empirical evidence regarding tool adoption, implementation and results achieved are summarized in Table III.

As emphasized by literature, tool testing confirms the key role of management in promoting internal assessment and the need to use appropriate tools supporting the assessment activities. In all five enterprises considered, the main source of tool attractiveness was represented by its complete and rapid assessment capabilities. The tool was considered as being easy to understand and to use, and any obstacles during its introduction were attributed to the lack of an internal sponsor, the presence of conflicts between involved managers, resistance to change by management or cultural barriers.

Tool implementation requires the involvement of persons belonging to various company areas (mainly, engineering design, production, purchasing, commercial-marketing) and is usually conducted with a group of four to eight people who are engaged in around five to seven meetings in relation to the participating enterprise's size and complexity. The difficulties that arose during tool implementation were not connected to intrinsic tool features but to organizational and cultural aspects; four enterprises out of five pointed out the difficulty in managing conflicts between members and/or had to solve problems connected to scarce motivation by participants or general management.

Table III. Main outcome resulting from on-field tests

	Alfa	Beta	Gamma	Delta	Sigma
Adoptiom					
Management problem inspiring an assessment of NPD	Ineffective coordination with manufacturing regarding transition to production/ramp-up	Time-to-market too long compared to competitors	Scarce understanding of market needs	Non-collaborative working relations between design and manufacturing	Inadequate orgaiñzation of design department
Tool attractiveness factors	Possibility to performe an overall assessment	Assessment rapidity Orgaiñzational integration	Assessment rapidity Orgaiilzational integration	Assessment completeness Tool originality	Assessment rapidity and completeness
Obstacles to tool adoption	Absence of internal sponsor supporting the project	Scarce interest by management towards tills type of analysis	Conflicts between managers on assessment process management	Part of management does not wish to change the existing situation	Enterprise's cultural level too low
Implementation					
Persons involved	Inter-functional working team of four people	Inter-functional working team of eight people	Inter-functional working team of six people	Inter-functional working team of seven people	Inter-functional working team of five people
Time to carry out the assessment	Five half-day meetings	Seven half-day meetings	Six half-day meetings	Seven half-day meetings	Six half-day meetings
Difficulties arising while using the tool	Difficulty in setting up the working team Conflicts between working group members	Scarce support by general management	Conflicts between working group members Scarce motivation of participants	Conflicts between working group members Low-priority project	Absence of a strong and motivated project leader Conflicts between working group members

(*continued*)

	Alfa	Beta	Gamma	Delta	Sigma
Results					
Tool capability of identifying management problems and of suggesting improvements	Good, problem perceived by management considered as high priority problem	Scarce, the tool highlighted aspects not considered as being important by management	Excellent, problem perceived by management considered as main critical area	Good, problem perceived by management considered as high priority problem	Acceptable, problem perceived by management considered as average priority problem
Tool completeness and functionality	Some practices considered to be not very coherent with company situation Difficulty in recognizing strategic-orientation priorities	Some scales considered to be not very clear Difficulty in identifying the correct level for each practice	Difficulty in understanding Relationship Matrix functioning Some issues do not appear in Questionnaire A	Some practices believed to be not very coherent with company situation Some scales considered to be not very clear	Some questions in Questionnaire A considered as not applicable
Improvement initiatives following the assessment	No programme developed, the enterprise was absorbed into a larger group	A project regarding orgaiñzational structure review was launched	The company will start out with a QFD project	A project has been released in order to implement DFM/DFA methodologies	No programme developed

Table III.

According to the management of the companies participating, the use of the tool pointed out important critical areas in four companies out of five; a partial incoherence between the aspects stressed by the tool and those perceived by the management was detected only in Beta. Owing to the evidence highlighted by the tool, three companies decided to set up further projects: Beta started up an organizational structure review, Gamma started up a QFD and Delta started up a DFM/DFA project. As to the two remaining companies, in one case strong company organization changes hindered continuation of the assessment phase and, therefore, the definition of suitable improvement programmes. In the other case, reasons for the lack of initiatives following the assessment activities are probably due to the fact that the tool detected critical areas that were not considered by management as being of priority concern.

The testing activities showed that there was room for improvement for the tool; in particular the terminology used to describe some best practices were considered as not being very clear, so it was necessary to revise the phrases used in the maturity scales: we have simplified descriptions and added clarifications of key concepts in order to be as clear and unambiguous as possible.

Furthermore, difficulties in recognizing strategic orientation priorities or in understanding how the relationship matrix worked were pointed out; difficulties also arose when applying some questions belonging to Questionnaire A. Following the testing activities, the research group introduced suitable modifications to the tool and to its implementation methodology in order to improve tool understanding and coherence with various application contexts. However, before carrying out these modifications, the opinions collected during the implementation phase and after termination of the analysis activities, confirmed the tool's ability to provide a clear and coherent representation of related company situations. The individuals involved considered the tool to be easy to understand and to use although they recognized the importance of implementing it with the support of an external consultant capable of handling the entire process.

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