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## Engineering and Design Best Practices in New Product Development: an Empirical Research

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### Abstract

Nowadays companies are subject to pressuring and challenging calls for innovation. New Product Development (NPD) becomes a crucial function for competitiveness, survival and prosperity. In order to deliver products successfully, companies can choose between a vast amount of best practices to apply in their innovation processes. This paper proposes a classification framework of prevalent NPD best practices obtained through literature investigation and focus groups with experts. Moreover, this study presents a research conducted in 2012 and 2013 across 103 companies based in Italy, with the aim to understand the level of implementation of the proposed framework of NPD best practices. Finally, starting from the analysis of the collected data, the paper contributes to the ongoing debate about the contingency of best practices: since *one size doesn't fit all*, is it correct to talk about best practices in general or should we start considering them context dependent? Data demonstrates that moving research towards this direction makes definitely sense.

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### 1. Introduction

The way companies innovate and introduce new products to the marketplace is critical for their competitiveness, prosperity and survival [1] [2] [3] [4] [5] [6]. The choice of engineering and design practices to be implemented in New Product Development (NPD) can drastically affect the success or failure of innovation processes. In literature a large number of engineering and design practices has been investigated and analyzed. Between those, a variety of best practices have been recognized to foster effectiveness and efficiency of NPD. Being NPD a multidimensional process, constitute of several layers and facets, some authors tried the effort of classifying NPD best practices across different dimensions [7] [8] [9].

Starting from previous literature contributions, and enriching them with a series of focus groups with experts, this paper first proposes a framework to categorize prevalent engineering and design best practices across three main dimensions: *Organization*, *Process* and *Knowledge*

*Management* (Section 2). Then, the proposed framework has been used to evaluate, through face-to-face interviews based on a semi-structured questionnaire, the level of adoption of those best practices within a sample of 103 national (Italian) and multinational companies. The exploratory research is reported in Section 3. Summary of the results of the study are discussed in Section 4.

### 2. The NPD Best Practices Framework

Any practice whether a technique, a method, a process, or an activity that enables to deliver more efficiency and/or effectiveness than any other manner can be considered as a *best practice* [7] [10]. Vice versa, we can define a *poor practice* [7] [10]. Given the multidimensionality of NPD, several best practices in literature have been tentatively grouped into classes, i.e. *strategy*, *research*, *commercialization*, *project climate*, *company culture*, *metrics*

and performance measurement, portfolio management, market research, people, process, and technology [1] [7] [11].

In this study, we identified prevalent best practices proposed in literature by different scholars [1] [7] [10] [11]. Basing on that, and on a series of focus groups conducted with experts, we came out with our own framework of NPD best practices. The focus groups were constituted by the members of the advisory board of GeCo Observatory - an Italian research initiative created in the frame of the Observatories of the Business School of Politecnico di Milano ([http://www.osservatori.net/progettazione\\_plm](http://www.osservatori.net/progettazione_plm)).

Particularly, 25 practitioners have been consulted together three times during the development and refinement of the framework, and their experience's based suggestions and feedback have been used to develop the final version of the framework, shown in *Table 1*.

The result we obtained is a list of prevalent NPD practices, strongly based on literature investigation and practical contributions.

The framework has been categorized within 9 areas (*Work Organization; Roles and Coordination; Training, Skills and Competencies; Process Management; Activities and Value; Decision Making Factors, Methods, Formalization, Computerization*) respectively grouped into 3 dimensions: *Organization, Process and Knowledge Management (Table 1)* [12]. However, potential hierarchical interrelationships between those three levels are not considered in this study.

The first dimension, *Organization*, concerns all the people involved in daily company's activities. Core areas are division of labor and tasks (*Work Organization*), coordination of people and activities, roles of engineers and designers (*Roles and Coordination*), skills and expertise of the practitioners (*Training, Skills and Competencies*) [1] [5] [8] [11] [16].

The second dimension, *Process*, investigates how NPD is practically performed. *Process* dimension is made of four areas: design rules and methodologies (*Methods*), control mechanisms and improvement of the process (*Process Management*), and how decisions are taken based both on internal strategy (*Decision Making Factors*) and competitors/customers (*Activities and Value*) [1] [5] [8] [11] [16]. The third dimension, *Knowledge Management*, is related to how companies create, share, represent and re-use their

Table 1. The NPD Best Practices Framework

Poor Practice	Best Practice
<b>Dimension 1: Organization</b>	
<b>Area 1: Work Organization</b>	
No formal NPD model Considerable amount of time is spent on wasteful activities Sequential non collaborative dev. process	Formal NPD model, properly followed and documented Considerable amount of time is spent for value adding activities Strongly collaborative development process
<b>Area 2: Roles and coordination</b>	
No definition of roles and responsibilities No flexibility on task execution No project responsible No formal process of allocating human resources in development projects	Clear definition of roles and responsibilities for individuals High flexibility on task execution There is an overall responsible with technical background Involvement of experienced designers from the earliest stages of the projects
<b>Area 3: Training, Skills and Competencies</b>	
Individual development of personal skills No trainer Visual assessment of training outcomes	Formal programs support multidisciplinary skills dev. One to one tutoring KPIs to assess training outcomes
<b>Dimension 2: Process</b>	
<b>Area 4: Process Management</b>	
No regular projects launch plan No KPI to measure NPD performance No particular focus on the first stage of NPD No specific plan for NPD improvement	Regular projects launch plan with no delays Complex set of KPIs to measure NPD performance Considerable efforts are made at the early stages of NPD Continuous Improvement Initiative
<b>Area 5: Activities and Value</b>	
A single solution is designed from the beginning to the end of the project No formal definition of value No customer involvement in development No competitors' analysis	Many solutions are designed, inferior solutions are progressively discarded when new info becomes available Complete focus on customer value Full customer involvement in development Formalized process for analyze competitors
<b>Area 6: Decision Making Factors</b>	
No impact of NPD choices on the life cycle No lifecycle perspective vision	High impact of NPD choices on the like cycle Lifecycle perspective vision
<b>Area 7: Methods</b>	
No formal engineering/design methods	Formal engineering/design methods
<b>Dimension 3: Knowledge Management</b>	
<b>Area 8: Formalization</b>	
No formal Knowledge management plan Main source of knowledge is given by personal contributions Formal sources of knowledge never updated Not considering previous knowledge Poor tools and techniques used to capture, share and reuse knowledge	Formal knowledge management plan Main source of knowledge is given by written design rules defined by the company Formal sources of knowledge continuously update and reviewed Rely on previous knowledge for NPD projects Various tools and techniques formally used to capture, share and reuse knowledge
<b>Area 9: Computerization</b>	
No software platform supports Knowledge Management within development process Data/information are not shared and owned by individuals	knowledge Management during development projects is strongly supported by software platforms such as PLM Data/information are stored and shared through collaborative and easy access IT supports

tacit and explicit knowledge. This perspective is made of two areas: *Formalization* (how knowledge is formalized and shared) and *Computerization* (how Information Technology, IT, tools and platforms are used for supporting knowledge storing, sharing and reusing along the NPD process) [1] [8] [11] [16].

From companies' perspective, this framework provides specific background and opportunity for best practice initiatives. Moreover, the identification of poor practices can be used to evaluate where to start with improvement initiatives.

2.1. The CLIMB Model

Based on the best practice framework, we developed a model named CLIMB [12], made of a *questionnaire* and a *radar chart*. The questionnaire investigates the usage of the NPD best practices. Each question, scored through a 5 points scale, is structured as in the following example (taken from the area *Training, Skills and Competencies*):

- How does the company support skills' development?*
- a. *Everyone is personally responsible for developing and maintaining his/her own skills* (1)
  - b. *A situation between a and c* (3)
  - c. *The company gives training on the job* (5)
  - d. *A situation between c and e* (7)
  - e. *The company promotes multidisciplinary skills with formal programs (i.e. training plans, rotation between project teams)* (9)

For each practice five different levels of accomplishment can be selected by the respondent: he can choose whether his company states at a poor practice level, at a best practice level, or somewhere in between. Those levels assume a score of 1 3 5 7 9, as reported in the blankets above. The lowest level of accomplishment (a), scored with 1, corresponds to one of the poor practice proposed in the framework, and the higher level (e) corresponds to the related best practice, and it is scored with 9. Additionally there are three middle levels, whose intermediate circumstance (c), scored with 5, is described in order to facilitate the respondent to address his choice.

The number of questions corresponds to the number of best practices investigated (Table 1). A group of one or more questions concurs to describe each of the 9 areas of the framework (Table 1). The score of a single area is calculated as an additive scale (summing the single scores of the questions describing the area) then normalized in %. Formula 1 defines how the score for each generic area (A<sub>i</sub>) is calculated.

$$a_i = \frac{\sum_{j=1}^{m_i} q_{ij}}{9 * m_i} \quad (1)$$

Where:

- a<sub>i</sub> is the score corresponding to i-th area, expressed in %
- i=1...9, is the indicator for the areas
- q<sub>ij</sub> is the score of the answer to the question j, belonging to the i-th area

j=1...m<sub>i</sub>, is the indicator for the questions, depending on the area the number of questions changes

m<sub>i</sub>, is the number of questions of the i-th area

9\*m<sub>i</sub> is the maximum score the area can assume in the case the respondent declares to always reach the best practice level –scored with 9– for all the j practices investigated within the i-th area.

Being each of the 9 areas expressed in %, we defined 5 possible stages of accomplishment of a best practice condition toward the i-th area. The 5 levels are basically 20% width intervals in the scale from 0 to 100% and are namely: *Chaos* (0%-20%), *Low* (21%-40%), *Intermediate* (41%-60%), *Mature* (61%-80%), and *Best Practice* (81%-100%) (see Fig. 1).

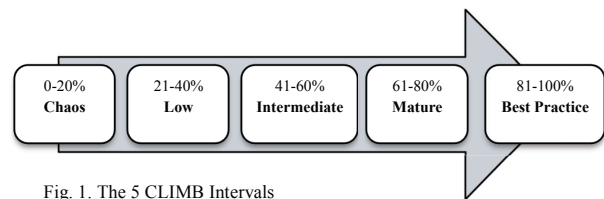


Fig. 1. The 5 CLIMB Intervals

The acronym of those intervals originated the name of the model: CLIMB [12]. The level of accomplishment achieved within each of the 9 areas can be then represented in a radar chart (see Fig. 2). The radar chart gives an immediate and effective picture of the level of implementation of the considered practices along the 9 areas of the framework (Table 1) and displays the positioning of the company within one of the 5 CLIMB stages (see Fig. 1). The proposed model will serve as basis for the empirical investigation described in the next sections.

3. The Empirical Research

In order to evaluate the level of diffusion of the identified NPD best practices within industry, we have run an exploratory research, from March 2012 to February 2013. The study has been conducted within the GeCo Observatory\* initiative on 103 national (Italian) and multinational companies. The investigation was based on the CLIMB model. Each interview involved either a project manager, a technical director, and/or a team of engineers working in NPD. An average of 2.5 hours have been spent in each company for each interview. This section introduces both the sample and some preliminary results of this study.

3.1. The Sample

The scope of the study was to explore the behavior companies have when adopting NPD practices. The sample is constituted of both small and medium enterprises (SMEs), and big enterprises. Details of the size of the sample are in Table

\* Italian research initiative created in the frame of the Observatories of the Business School of Politecnico di Milano ([http://www.osservatori.net/progettazione\\_plm](http://www.osservatori.net/progettazione_plm)).

2. Companies belong to different sectors, which could be grouped into 4 main classifications: Mechanics, Electrics, Electronics and Other Sectors (such as Fashion, Chemical and Food). Table 3 summarizes the distribution of the sample along the sectors.

Considering the engineering systems chosen by companies in designing, manufacturing, and delivering their product, we can distinguish, within our sample, between different kinds of approaches. Some companies are following a pure Engineering to Order (ETO) system, Make to Order (MTO), or Make to Stock (MTS), some other companies are tending versus a combined approach. A summary is in Table 4.

Table 2. The Sample: Sizes

Size (based on number of employees)	N° of companies	Class	N° of companies
Micro (<10)	4		
Small (10>employees<50)	13	SMEs	38
Medium (50>employees<250)	21		
Big (250>employees<1000)	29	LARGE	65
Macro (>1000)	36		

Table 3. The Sample: Sectors

Sector	N° of companies
Mechanics	44
Electrics	27
Electronics	18
Other	14

Table 4. The Sample: Engineering Systems

Engineering System	% of Sample
ETO	39%
MTO	38%
MTS	11%
Mix	12%

3.2. Hypotheses and Preliminary Results

The radar chart resulted to be very effective to represent the as-is situation in adopting NPD best practices within companies. The 5 levels of the CLIMB model are displayed in the radar chart of Fig. 2. The sample presents high variability on the data: almost all five different CLIMB levels for the 9 areas were found across the sample. Fig. 2 displays the average trend in the use of best practices within the 103 companies of the sample.

Some areas result to be, on average, more mature and well performed than others. Main weaknesses are in the area of formalization of knowledge and usage of formalized engineering and design methods, which companies, on average, accomplish only at intermediate level.

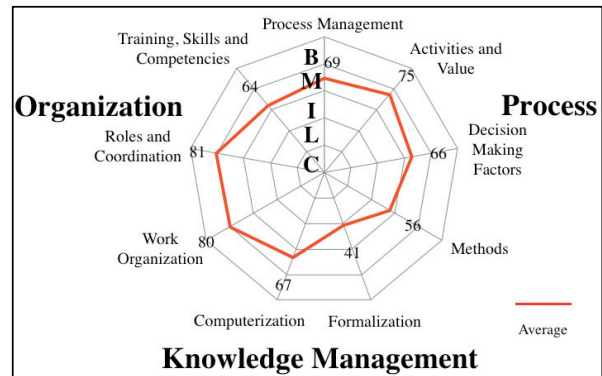


Fig. 2. Radar Chart: Global Average of the Sample (values in the radar are %)

One could expect SMEs and large companies having different attitudes in their product development approaches. Similarly one could expect that companies belonging to different industries behave differently. Fig. 4 shows the trend of large companies versus SMEs and Fig. 3 displays the trend within the 4 different sectors analyzed. The graphical results seem not to support the general belief that SMEs and large companies are drastically different. Moreover this thought seems to apply for sectors as well.

To test this assumption we performed One-way Anova in our data (see Table 5). We tested 2 main hypotheses.

H1, the means of SME and LARGE companies are the same in the following areas:

- H1.a Training, Skills and Competencies
- H1.b Roles and Coordination
- H1.c Work Organization
- H1.d Process management
- H1.e Activities and Value
- H1.f Decision Making Factors
- H1.g Methods
- H1.h Computerization
- H1.i Formalization

H2, the means of different sectors (Mechanics, Electrics, Electronics, Other) are the same in the following areas:

- H2.a Training, Skills and Competencies
- H2.b Roles and Coordination
- H2.c Work Organization
- H2.d Process management
- H2.e Activities and Value
- H2.f Decision Making Factors
- H2.g Methods
- H2.h Computerization
- H2.i Formalization

According to the value assumed by the p-value we can accept all the sub-hypotheses formulated, except for the following:

- H1.a Training, Skills and Competencies;
- H1.d Process management;
- H1.h Computerization;
- H2.g Methods
- H2.h Computerization.

Table 5. One-way Anova

One-way Anova results (n=103)	
H1: the means of SME and LARGE companies are same in the following areas:	p-values
H1.a Training, Skills and Competencies	0.0428*
H1.b Roles and Coordination	0.6551
H1.c Work Organization	0.1954
H1.d Process management	0.0002***
H1.e Activities and Value	0.0884
H1.f Decision Making Factors	0.6531
H1.g Methods	0.3726
H1.h Computerization	0.0016**
H1.i Formalization	0.0919
H2: the means of the different sectors are same in the following areas:	p-values
H2.a Training, Skills and Competencies	0.9576
H2.b Roles and Coordination	0.9726
H2.c Work Organization	0.1685
H2.d Process management	0.2803
H2.e Activities and Value	0.2627
H2.f Decision Making Factors	0.0519
H2.g Methods	0.0102*
H2.h Computerization	0.0004***
H2.i Formalization	0.9298
***p < 0.001, **p < 0.01, *p < 0.05	

This means that SMEs and large enterprises are statistically different in managing their NPD process, and in training and developing skills and competencies of people. Differences between SMEs and large enterprises are also found in term of knowledge computerization; differences in this sense either exist from sector to sector. Moreover, companies belonging to different sectors show differences on the methods they apply for supporting their development processes.

Differences found in data could be justified because of SMEs are usually less organized and they lack strong structure to perform process management and formalized training activities. SMEs usually have less financial possibility to invest in sophisticated IT tools, moreover their less structured organizations usually don't promote highly computerized knowledge management. Across sectors, differences are justifiable because of the different nature of different industries or because of the maturity of the sector itself: some sectors seem to be more mature and more willing to implement highly computerized tools, such as PLM systems. Moreover different industries can rely on different methods to support their product development activities.

Beside these proven differences, the other areas investigated don't report statistically significant differences between SMEs and large companies or across sectors. This result looks quite surprising. It seems both size and sector, alone, are not sufficient to justify the choice of NPD best practices companies implement.

If size and sector stand-alone, cannot explain the differences in companies' behaviors, what else can subsist to

justify different attitudes? What makes a company choose between a best practice to be implemented over another one? Can we find some casual link?

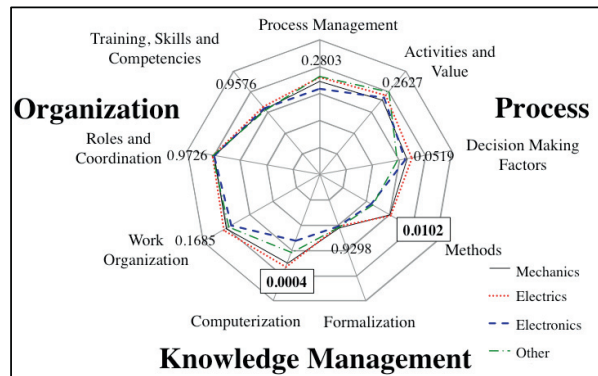


Fig. 3. Radar Chart: Sectors (values in the radar are p-values)

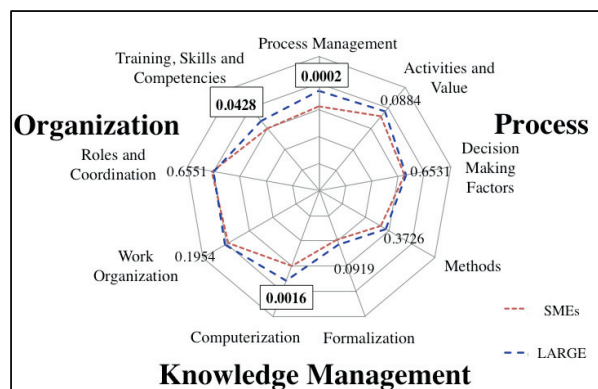


Fig. 4. Radar Chart: SMEs vs LARGE (values in the radar are p-values)

#### 4. Conclusions

Companies in order to assess them and to address their improvement efforts can use the CLIMB model. Moreover it can also be a useful tool for benchmarking purposes [7] [12].

In term of results, if we look at each single area, the sample presents both poor practices and best practices, touching all points of the 5 levels of the CLIMB model. However, in average terms, data don't reveal high differences concerning size or sector. This suggests the existence of hidden patterns behind the implementation of NPD practices but the reasons for the differences in behaviors should be found elsewhere from merely sector and size.

These results have led us towards a deeper reasoning on the factors that mainly determine the choice of some engineering and design practices to be adopted versus others. A first idea is that some practices are more willing to be used in certain circumstances and that *one size doesn't fit all*. As other literature streams suggest, even for NPD practices the influence of the contingency factors are paramount [13]. Moreover, there is a general discussion whether there is a general set of best practices which are always effective, or

they are context or industry specific [7] [14]. More research, however, is needed on which practices are more suitable to be used in which context. Furthermore, this open issue encourages the reasoning on whether each circumstance and context require the use of a unique set of practices or whether there exist very typical repeatable examples of certain combination of practices suitable to be used in certain situations.

#### 4.1. Current and Future Research

The data briefly shown in this paper open the door to a bigger research which is currently ongoing. The aim is to explore the existence of common and repeatable patterns followed by companies in the implementation of best practices in their innovation processes. Collected data are now under statistic evaluation and the desired result is to identify causality links between variables (namely, each of the identified best practice). Furthermore we would like to explain the repeatability of patterns followed in the choice of engineering best practices to be implemented, through the identification of *archetypes*, which we define as very typical examples of certain combination of practices [15]. This implies that to explore the existence of common and repeatable patterns followed by companies in the implementation of best practices in their innovation processes. This requires the implementation of statistics tool such as exploratory factor analysis and cluster analysis.

#### 4.2. Managerial Implications

There are several practical contributions of this research. First, it is proposed a contribution to knowledge in term of a possible way to categorize engineering and design best practice, based on literature review and experts contribution. The CLIMB model, which embeds the proposed best practices framework, results to be useful both in term of self-assessment and for benchmarking purposes. Second, the levels of adoption of NPD best practices across companies are investigated, with a focus on the main critical areas characterized by a poor use of good practices. Moreover, the scientific relevance given by the introduction of different profiles based on the NPD best practices (*archetypes*) represent an important contribution to knowledge in this sense. NPD best practices will be considered as an ingredient of a more comprehensive *recipe of innovation*. The contribution will be both to understand which different *ingredients* can be appropriately combined together, and to provide a list of *recipes*, to be prepared according to different contexts. In other words this research will contribute to the debate that is going on about the meaning of NPD best practices, considering that one size doesn't fit all, that single practices are contingency dependent, and that a best practice can be more effective if used in combination with others depending on a particular industrial context. Managers will gain benefits and practical insights from this discussion.

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