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GUIDELINES FOR A DECISION SUPPORT METHOD ADAPTED TO NPD PROCESSES

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ABSTRACT

In the present paper a study of decision making processes in innovative Small and Medium Sized Companies from the Valencia region (Spain) is presented. The objectives of the study are: to determine what relevant groups of decisions are made in New Product Development, to determine how these decisions are made in this type of companies, to demonstrate that these companies do not as yet use Decision Support Methods and to obtain guidelines for a future development of a Decision Support Method adapted to these type of decisions and companies.

To achieve these objectives, an empirical study covering a representative sample of innovative companies in this region was carried out.

On one hand, the patterns of decision-making processes in these companies were obtained, extracting the main groups of decisions through a factorial analysis of the data. On the other hand, after a reliability analysis and a data correlations study, these results also show that two different company groups can be identified, according to the structure level of their decision-making processes. The existence of these two groups allowed us to identify different ways to support these companies in making these types of decisions.

Keywords: NPD, decision making, survey

1 INTRODUCTION

Innovative companies seek competitive advantages by identifying explicit and implicit market needs, satisfying them with new responses and dedicating their resources to produce new ideas and alternatives. In most cases, this procedure is materialised by the launching of new products or by the improvement of existing ones. Companies that do not fulfill this in an efficient and effective way end up losing competitiveness in ever tougher markets [1].

Since the level of a firm's competitiveness is closely associated to its capacity for adaptation to its surroundings, we therefore assume that the optimization of the decision processes will improve its competitiveness. Within this framework, the success of the New Product Development (NPD) process depends, among other factors, on the integrated decision making ability of the system [2].

Several references found in the Literature address decision processes developed within the NPD [3], [4], [5], [1]. From all these works we want to emphasise the one by Krishnan and Ullrich [5], in which a total amount of 200 references related to NPD decision processes were analysed.

We will assume that product development is a *deliberate business process involving scores of such generic decisions* [5] and therefore will focus our work in analysing such decisions. Based on a previous work of the authors of this paper [6] in which the main NPD decisions were identified, we now try to group these decisions in order to identify common procedures patterns within these groups. We understand under the word *decision*, choices that managers have to make during the NPD process (see annex 1).

Decision Theorists often characterize decision processes by their structure. In this way, some authors distinguish between processes [7], approaches [8], environmental [9], or problems structure [10]. They all follow the programmed/non programmed problem dichotomy proposed by Simon [11]: structured (or well-structured) and un-structured (or ill-structured). Hence, we assume NPD decision processes can be classified according to these categories: Structure Decision Model – Ill-structure Decision Model (henceforth S-IS).

2 OBJECTIVES

The aim of the present work is to carry out an empirical study, which covers a representative sample of companies in the Valencian Region (VR), a region characterized by having a great number of Small and Medium Size Enterprises in dispersed industrial sectors [12]. The main objectives are:

- to determine what relevant groups of decisions are made in New Product Development,
- to determine how these decisions are made in this type of companies,
- to demonstrate, as is shown in the Literature, that these companies do not as yet use Decision Support Methods (DSM),
- to obtain guidelines for a future development of a Decision Support Method adapted to these type of decisions and companies.

3 METHODOLOGICAL PROCEDURE

This empirical study has been carried out on a representative sample of innovative companies in the VR.

3.1 Questionnaire design

The documentation was carefully prepared so that the people asked (henceforth *experts*) could devote their time to concentrate on the issue and provide their knowledge and experience and not to administrative or bureaucratic tasks. Each expert was provided with one questionnaire and for each question had to choose the answer that best suited him.

The questionnaire was divided into two parts:

1. List of the most common decisions made in companies that develop new products, based on conceptual grouping proposed by Krishnan and Ullrich [5], (see Annex 1, part I & II). The objective of this first part was to inquire whether decisions considered usual in the literature were actually common within the framework of innovative companies in the VR and to find out if the conceptual grouping of the mentioned decisions does adjust with the empirical data obtained.

2. Decision-making patterns in companies.

- A number of questions were asked to find out the patterns of decision-making processes in those innovative companies and their Decision Models (S-IS) (See annex 1, part III, *About the Decision Model*). Therefore, the contents of this part of the questionnaire were based on the elements suggested by [9] and [10] in their definition of structured and ill-structured decision models. These decision models are distinguished as follows:

  - A structured decision model (or well-structured decision model): the objectives are clear and the feasible alternative solutions are often obvious. A well-structured decision model is characterized by the following elements:
    - It defines the decision problem to be addressed.
    - It identifies key objectives to clarify what you want your decision to achieve.
    - It describes consequences in terms of how each alternative meets the objectives.
    - It identifies ”what matters” in the context of the impending decision in the form of the stakeholders objectives.
    - It examines how the outcome of this decision will influence future decisions [9].
  - An ill-structured decision model: tends to be complex, non-routine and difficult to define. Potential alternative solutions, objective(s) associated with solving these problems, and the relevant decision makers and stakeholders, are often not obvious. An ill-structured decision model is characterized by the following elements:
    - Task objectives (problem solutions) and outcomes may be ambiguous and/or conflicting.
    - It is difficult to understand the effect of changes on decision outcomes and to predict (in advance) the effect of the actions.
    - Uncertainty exists concerning which actions affect the outcomes.
    - Human decision makers often use imperfect, subjective, and informal methods to process incomplete and imprecise knowledge [10].

- The second aim was to determine whether the decisions made were of the type multi-criteria, multi-expert and discrete, as well as to get to know the degree of usage of DSM (See annex 1, part III, *About the Decision Process Characteristics*).

3.2 Sample choice

In order to establish a representative population for the study we had to define:

- *Target population*: all innovative companies in the VR.

- *Sampled population*: 1200 companies in different sectors of the VR catalogued as innovative in the DIRNOVA data-base.

- *Sample size*: calculated by arbitrary sampling of finite populations. This calculation indicated that the minimum sample size needed was 124 responses.

- S*ample frame*: the support used to deliver the questionnaire was a mailing to the attention of the General Manager of each company. That way we wanted to make sure that the questionnaire would be handed in to people with decision capacity and a global view of the company.

3.3 Data collection

After gathering all the reports, the obtained data were analysed. Once the lost values had been removed (reports from companies that did not answer the whole questionnaire) the sample used consisted in all the answers obtained from the companies. The number of answers received was 136, which was considered a representative sample according to the sample size already calculated.

3.4 Results analysis

The results of the questionnaire have been treated in the following way:

- by carrying out a factorial analysis to find out the way the decisions analysed can be grouped.
- by carrying out a frequency distribution analysis to discover how these decision processes were classified and a reliability analysis and a data correlation study to show that two different company groups can be identified, according to the Decision Models (I-IS).

3.4.1. Results parts I & II

The first study carried out consisted in a multivariant analysis. This analysis was based on a factorial analysis of the answers obtained in order to group all the questions (type of decisions made) into more general categories.

The possible answers for each question referred to the frequency with which the specified decisions were made (see annex 1, part I&II)). The proposed answers were assigned the following marks: *Never* = -2, O*ccasionally* = -1, *Often* = 1, *Always* = 2.

The results obtained from the factorial analysis carried out for the questions of the first part (Part I), *product development* questionnaire, are presented in Table 1. These results show that the 18 original variables (defined as DNP variables in the whole analysis) are represented in five new axes, which could be the factors responsible for the variability detected.

Table 1.- New Product Development Variables. Factorial Analysis (Varimax rotation method)

	Factor				
	1	2	3	4	5
DNP13	,850				
DNP12	,810				
DNP15	,778				
DNP14	,643		-,204		
DNP16	,637				
DNP9	,384			,247	
DNP7	,333		-,295	,219	
DNP11		,839			
DNP10		,777			
DNP1			-,778		
DNP2			-,759		
DNP3			-,598	,306	
DNP5				,831	
DNP4				,702	
DNP6				,506	,253
DNP8	,250	-,227		,443	
DNP17					,877
DNP18					,826

On one hand, DNP7, DNP8 y DNP9 variables are correlated with several factors are not clearly grouped under any new variable. Therefore, no important factor that overclassifies them can be found as shown in the study [5] carried out. On the other hand, DNP1, DNP2 and DNP3 variables are correlated with a different factor to the one that DNP4, DNP5 y DNP6, hence they can not be grouped.

The 18 original variables could be grouped into 5 new variables. That means that the decisions that appear in the questionnaire can be classified within 5 groups. However, this result does not coincide with the classification proposed in [5] which means that the results obtained for the VR do differ from the ones obtained for the bibliographical study. As it can be observed, a new factor appears: *About the variants of the product* under which variables DNP4, DNP5 y DNP6 can be grouped. It can also be noted that the factor related to *product design* disappears because the decisions grouped under it can be also classified under the other four factors.

Moreover, the results obtained from the factorial analysis carried out for the second part (Part II), *setting up and development project* questionnaire, it can be observed that the 16 original variables (defined as PM variables in the whole analysis) are now represented in three new axes or factors. Therefore, 3 main groups are obtained to classify the questions stated in the questionnaire. This result does coincide with the one obtained by Krishnan and Ullrich.

Table 2.- Project Management Variables. Factorial Analysis

	Factor		
	1	2	3
PM16	,831		
PM12	,762		
PM8	,709		
PM10	,704		
PM13	,703		
PM11	,640		
PM14	,501		
PM15	,462		-,324
PM2		,880	
PM3		,870	
PM4		,644	
PM5	,267	,409	
PM7			-,836
PM6			-,824
PM1		,260	-,493
PM9	,259	,234	-,341

Variables PM1 y PM9 are correlated with several factors. It can be noted that variable PM1 could be grouped together with PM2, PM3, PM4 and PM5, as shown in the study [5] but it also affects the factor under which variables PM6 y PM7 are grouped. However, variable PM9 affects all three factors which jeans that it could not be a priori grouped under any of these decision types.

3.4.2. Results part III

The possible answers for each question related to the way they made their decisions are: *Never* = -2, *Occasionally* = -1, *Often* = 1, *Always* = 2. They are defined by means of an ordinal scale, converted to a dichotomised nominal scale, grouping positive answers (always and often) as *generally yes* and negative answers (never and occasionally) as *generally no*.

The following Table shows the results of the questionnaire regarding to the frequency distribution of all the variables that define the decision model (DMP1, DMP2, DMP3, DMP4 and DMP5) and

also those of variables (form DMP6 to DMP12) which identify decisions as of the type multi-criteria multi-expert discrete, as well as the frequency of DSM usage.

Table 3.- Frequency Distribution results

Question	*Generally Yes*	*Generally No*
Decision Model		
DMP1. Do you think you are given enough time to make decisions?	56.59 %	43.41%
DMP2. Do you specifically define the objective you wish to achieve with the decision process?	79.07%	20.93%
DMP3. Do you consider how your decision will affect your company as an organisation?	78.29%	21.71%
DMP4. Do you consider the effect your decision may have on stakeholders?	69.77%	30.23%
DMP5. Do you consider the consequences in terms of how each alternative meets the objectives?	58.14%	41.86%
Decision process characteristics		
DMP6. When making a decision only the economic criterion is considered?	16,28%	83,72%
DMP7. Is the decision analysed from different points of view or criteria?	93.02%	6.98%
DMP8. The decisions are always made by the person in charge individually?	13,95%	86,05%
DMP9. The decisions are always made by the person in charge with the support of experts?	74,34%	25,66%
DMP10. Are the decisions made within a group?	94,57%	5,43%
DMP11. When a decision has to be made a group of well defined alternatives is stated?	86,67%	13,33%
DMP12. During the decision making process, do you use any particular Decision Support Method?	14,73%	85,27%

The frequency distribution of the first 5 variables reflect a positive tendency in the answers towards a structured decision model. However, no single model clearly predominates (as can be seen in Table 3). In view of these results, it was decided to carry out an analysis of this scale (questionnaire composed of these first five questions and which defined the decision model), for two reasons; firstly to discover whether the questionnaire was sufficiently consistent to provide a reliable measure of the model, and secondly to discover whether the companies utilise a model that could be defined as structured or ill-structured. The results are shown below.

The measurement of reliability used was Cronbach's Coefficient Alpha. The results are as follows:

Table 4.- Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha based on typical elements	N of elements
,714	,713	5

The value of the result given by Cronbach's Alpha is greater than 0.7, which indicates that the questions proposed are reliable and internally consistent. The reliability offered by the questionnaire also indicates that this measurement would give the same results in successive tests.

It was also decided to analyse the relevant results of the items of the questionnaire in order to identify problematic elements to be reconsidered or excluded. The following Table shows the results of the inter-element correlation matrix (items or variables) and a summary of the statistics that compare each element with a scale composed of all the other elements.

Table 5.- Inter-element correlation matrix

	DMP1	DMP2	DMP3	DMP4	DMP5
DMP1	1.000	.051	-.076	-.031	.081
DMP2	.051	1.000	.712	.648	.336
DMP3	-.076	.712	1.000	.766	.433
DMP4	-.031	.648	.766	1.000	.396
DMP5	.081	.336	.433	.396	1.000

Table 6.- Total-element statistics

	Mean of the scale with element eliminated	Variance of the scale with element eliminated	Corrected total-element correlation	Squared múltiple correlation	Cronbach's Alpha with element eliminated
DMP1	2.92	22.791	.011	.043	.819
DMP2	2.15	15.986	.650	.542	.599
DMP3	2.10	15.107	.699	.687	.573
DMP4	2.48	14.877	.666	.613	.582
DMP5	2.81	16.074	.439	.210	.685

It can be seen from these results that high inter-element correlations exist except in the case of DMP1 with the others. An analysis of the statistical results of the rest of the scale, if each of the elements was eliminated, concludes that the correlation between DMP1 and the scale composed of the other elements is very low and also that the Cronbach's Coefficient Alpha without this item is much higher (0.819). This means that the scale would be more reliable and consistent without it. It can also be observed that significant correlations exist among variables DMP2, DMP3, DMP4 and DMP5. They all have a positive relationship with each other, which indicates that the association existing among these elements tends to be in the same direction (structured or ill-structured model).

3.4.3.- Discussion of the results.

Factorial analysis allows the grouping of the NPD most common decisions. Each factor represents a type of a common NPD decision. This study provides the development of specific Decision Support Methods.

Regarding the questions about the Decision Model we want to stand out that one of the results that has surprised us is that more than 50% of the managers declared to devote enough time to make decisions, although the general feeling is to never have enough time to make decisions. Moreover, most of the people considered that when making decisions the objectives are clearly stated, and the consequences related to the organizations and stakeholders involved are taken into account.

On the other hand, according to the reliability analysis results, many of the companies in the sample deal with important decision problems in a structured way. However, a fairly high percentage of them

approach decision problems with an ill-structured model. The companies can be categorized according to the decision model they follow.

Most of the people answered that they use different criteria when making a decision and not only the economic criterion as could be assumed. The results obtained for DMP8, DMP9 and DMP10 show that most of the managers do not make decisions by themselves but with the support of their staff or experts. The results obtained for DMP11 show that most of the answers indicates that the type of decision problems faced by the managers have concrete alternatives (discrete) and are not multi-objective decision type which are more related to technical problems. The results obtained for DMP12 show that most of the people declare that they do not use MCDA techniques.

All in all, we can conclude that innovative SMEs in the Valencia region follow a multi-criteria multi-expert discrete type decision process, but without the help of any MCDA method.

4 CONCLUSIONS

An empirical study to inquire whether the usual groups of decisions reported in the literature are actually common within the framework of innovative companies in the Valencian Region has been carried out. The empirical study was conducted by means of a questionnaire including all NPD decisions identified. The aim was to determine the way these decisions can be conceptually grouped. The analysis of the results confirmed that the decisions identified in the literature do correspond to the decisions mostly made in innovative companies of the VR.

At the same time the empirical study has been used to find out the patterns of NPD decision-making processes in those innovative companies. The results show that it is possible to establish a common procedure for companies which follow a structured decision model as well as for companies which follow a ill-structured decision model, since both groups are dealing with multicriteria multiexpert discrete NPD decisions. The existence of these two groups will allow us to develop another study, to obtain more detailed information about the decision making procedures of each of the two company categories.

In addition to that, since most of the people interviewed admitted not having used any DSM, we consider that this lack of tools can be solved by proposing specific DSMs which can be adapted to their Decision Making problems.

The NPD decisions related to *product development* (NPD variables) can be grouped in five new concepts:

- About Concept Development
- About Performance, Testing and Validation
- About Supply Chain Design
- About the production ramp up
- About the variants of the product

The NPD decisions related to *setting up and development project* (PM variables) can be grouped in three new concepts:

- About Product Strategy and Planning
- About Product Development Organization

- About Project Management

Eight main types of NPD decisions can therefore be obtained. It would be useful to develop a DSM for them based on the following assumptions:

- The most suitable techniques to use in these decision making processes are those that belong to MCDA techniques.

- The DSM must provide the companies with the necessary guidelines to solve NPD decisions adapted to both structured and ill-structured model.

Based on the results of this study, a Decision Support Method will be proposed based on Discrete Multicriteria Analysis, with the goal of supporting the decision makers and therefore achieve the improvement of the NPD process efficiency.

5 FUTURE WORKS

In order to prove the relationship between NPD decision making processes and their structure level, another empirical survey is being carried out at present, whose results will be published in the very next future.

Based on the results of this study, a Decision Support Method will be developed focused on Discrete Multicriteria Decision Analysis, with the goal of supporting the companies attending their structure level in the decision-making processes in making right and intelligent decisions and therefore achieve the improvement of the NPD process efficiency.

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ANNEX 1. QUESTIONNAIRE

Part I: Product development decisions made within a Project

	I have made this particular decisión…			
Have you made the decision?	Never	Occasionally	Often	Always
About Concept Development				
NPD1. What are the target values of the product attributes, including price?				
NPD2. What is the core product concept?				
NPD3. What is the product architecture?				
NPD4. What variants of the product Hill be offered?				
NPD5. Which components Hill be shared across which variants of the product?				
NPD6. What Hill be the overall physical form and industrial design of the product?				
About Product Design				
NPD7. What are the values of the key design parameters?				
NPD8. What is the configuration of the components and assembly precedent relations?				
NPD9. What is the detailed design of the components, including material and process selection?				
About Performance, Testing and Validation				
NPD10. What is the prototyping plan?				
NPD11. What Technologies should be used for prototyping?				
About Supply Chain Design				
NPD12. Which components will be designed and which will be selected? Who will design the components?				
NPD13. Who will produce the components and assemble the product?				
NPD14. What is the configuration of the				

physical supply Chain, including the location of the decouple point?				
NPD15. What type of process Hill be used to assemble the product?				
NPD16. Who will develop and supply process technology and equipment?				
About the production ramp up				
NPD17. What is the plan for market testing and launch?				
NPD18.What is the plan for production ramp-up?				

Part II: Decisions in setting up and development project

	I have made this decision…			
Have you made the decision?	Never	Occasionally	Often	Always
About Product Strategy and Planning				
PM1. What is the market and product strategy to maximize probability of economic success?				
PM2. What portfolio of product opportunities will be pursued?				
PM3. What is the timing of product development projects?				
PM4. What, if any, assets (e.g. platforms) will be shared across which products?				
PM5. Which Technologies will be employed in the product(s)?				
About Product Development Organization				
PM6. Will a functional, Project or matrix organization be used?				
PM7. How will the team be staffed?				
About Project Management				
PM8. Hoe will Project performance be measured?				
PM9. What will be the physical arrangement and location of the team?				
PM10. What investments in infrastructure, tools and training will be made?				
PM11. What type of development process will be employed (e.g. stage-gate)?				
PM12. What is the relative priority of development objectives?				
PM13. What is the planned timing and sequence of development activities?				
PM14. What are the major Project milestones and planned prototypes?				
PM15. What will be the communication mechanism among team members?				
PM16. How will the Project be monitored and controlled?				

Part III: Decisión making process characteristics

	Never	Occasionally	Often	Always
About the Decision Model				
DMP1. Do you think you are given enough time to make decisions?				
DMP2. Do you specifically define the objective you wish to achieve with the decision process?				
DMP3. Do you consider how your decision will affect your company as an organisation?				
DMP4. Do you consider the effect your decision may have on stakeholders?				
DMP5. Do you consider the consequences in terms of how each alternative meets the objectives?				
About the Decision Process Characteristics				
DMP6. When making a decision only the economic criterion is considered?				
DMP7. Is the decision analysed from different points of view or criteria?				
DMP8. The decisions are always made by the person in charge individually?				
DMP9. The decisions are always made by the person in charge with the support of experts?				
DMP10. Are the decisions made within a group?				
DMP11. When a decision has to be made a group of well defined alternatives is stated?				
DMP12. During the decision making process, do you use any particular Decision Support Method?				