A 2-TUPLES MODEL FOR THE NEW PRODUCT DEVELOPMENT PROBLEM

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Abstract. In more and more uncertain environments, the companies find that the satisfying the needs of the consumers is not a strategic option but a strategic necessity. The traditional models recognize the necessity of working with qualitative information on the voice of consumer, but the literature has not put forward any appropriate methodology. Thus, this paper tries to respond to this drawback permitting to operate with linguistic information by means of 2-tuples linguistic representation.

1. Introduction

The aim of this paper is to present a model making it possible to determine the technical characteristics that should be incorporated into a new product. This would be done by optimizing the information available about consumer preferences, so that their requirements are taken into consideration from the beginning of the process of New Product Development (NPD).

The justification for the need to set up a model such as the one proposed here lies in the fact that the economic environment in which firms operate is characterized by great dynamism, implying large changes in economic and market conditions, combined with ever-swifter technological advances. In such circumstances, businesses must adjust their range of products continually, modifying or discontinuing current items and launching new products. In this way, the development and introduction of new ranges becomes a key element in companies' survival and growth.

In this sense, it may be observed that the process of NPD commences with customer expectations and concludes with the appearance of a finished product. Hence, the core question is one of translating client expectations into specifications internal to the firm and of transmitting these faithfully to the various divisions of the business that are involved.

In fact, customer expectations, which are the starting point for the development cycle and process, may be distorted and delayed in reaching those who have to convert them into the concrete tasks that must be performed to achieve a finished product. Thus, complete transmission of the information associated with the product, its rapid circulation and collaboration without reserve by all the divisions of the firm that share a common goal at a given moment are factors that offer a measurement of the agility and capacity to react of the business under consideration.

The ideas put forward above clearly show the need for a business to have some mechanism that permits the transformation of requirements expressed by potential customers into a set of product characteristics constituting the best combination possible.

On these lines, the second section of the paper presents a model for NPD that attempts to bring together both perspectives, by analyzing what variables should be considered, both from an external viewpoint (customer statements) and from within the firm itself (the statements made by design staff). Such a model strives to overcome the two limitations present in traditional models that constitute the main focus of attention of this paper, to wit:

Firstly, the need to adopt mechanisms permitting operations with linguistic information. In fact, the relevant information (customer voice) is obtained in most cases in the form of opinions expressed by people, that is, in linguistic terms. This implies to establish mechanisms must permitting clients to state their opinion in the terms or expressions that are most familiar to them, without requiring the imposition either of a specific form of expression or of the number of values that must be used in statements. Thus, in the third section, we analyze mechanisms that allow operation with linguistic information. In concrete, we are chosen a 2-tuples linguistic representation, which makes the procedure for aggregating multi-texture linguistic information easier. Thereafter, in the fourth section the principal lines of operation of the model for NPD are defined. Finally, the principal conclusions arising from the study undertaken are set out in the fifth section.

2. Development of New Products: General Considerations

In an environment of changes in economic and technological conditions, together with an increased level of competition, both local and global, variations in consumer needs, the rapid obsolescence of products and the emergence of new markets, it is essential for firms to respond quickly in the development of new products ([4], [9], [12], [20]). In general, it is accepted that a rapid response to the market can yield a substantial gain in future market share, as reflected by the conclusions reached by a number of studies (among others, [21], [8], [5]).

In addition, the uncertainties present in markets and technology imply that such processes should be carried out in a flexible way, with the aim of minimizing the risks in the project, as any process of innovation brings with it an inherent market and technological risk [16]. The market risk derives from the degree of originality and complexity of conception of the new product, while the technological risk is determined by the degree of innovation in the technology used. In both cases this is from the viewpoint both of the market and of the firm itself. Both sorts of risk can provide an explanation for the high failure rates affecting the development of new products ([7], [10]).

Moreover, the literature offers a range of studies attempting to identify the factors determining the success of new products in the market, so as to improve the efficiency of the process of new product development ([17], [18], [11], [15], [19]). Between the works that recognize that one of the main factors of success in the NPD consists of satisfying the needs of the consumers are [1], [3], [6] and [2]. Another factors for success is the way in which the process of NPD is carried out is of particular relevance, because, as Fig. 1 shows, it starts with consumer expectations and ends with the appearance of a finished product.

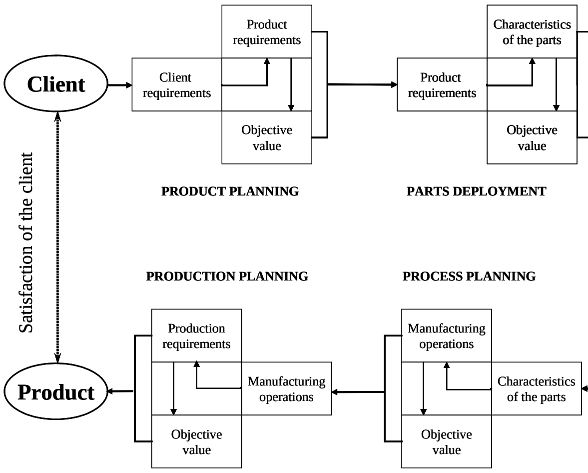

Fig. 1. New product development process

Thus, we need to translate consumers' expectations into specifications for use within the business and to transmit such specifications faithfully to the various divisions involved is not to be achieved without difficulty, as it commonly runs up against numerous obstacles, whether arising from the firm's structure, from its operational procedures or from the very nature of the development process. In its turn, the conversion of consumer requirements into fully detailed technical design specifications may be a hard task, since client needs are often fuzzy or vague, and in many cases contradictory. Indeed, as technical specifications for a product are expressed in a sort of language quite different from that used in stating consumer necessities, the voice of the client is frequently not heard fully clearly and the end result is a product that does not completely satisfy consumer requirements.

Thus, with the object of building a model that will permit determination of what combination of characteristics should be incorporated into NPD, the analysis to be carried out must first of all consider the variables affecting both potential technical features and requirements stated by clients. This will allow any possible relationships between these two types of information to be noted.

In this way, a list of the various requirements (requirements of consumers) put forward for the new product can be taken into consideration, such as: $RC_i \ with \ \ i = 1,2,...,n$ together with characteristics (characteristic aspects) that might be built into it $CA_j \ with \ j = 1,2,...,m$

This initial information may then be reflected in a double-entry matrix in which any relationships (r_{ij}) between the variables can be specified, as follows:

$$\lfloor CA_1 \ \ ... \ \ CA_j \ \ \ ... \ \ CA_m \rfloor$$

$$\begin{bmatrix} RC_1 \\ \ldots \\ RC_i \\ \ldots \\ RC_n \end{bmatrix} \quad \begin{bmatrix} r_{11} & \cdots & r_{1j} & \cdots & r_{1m} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ r_{i1} & \cdots & r_{ij} & \cdots & r_{im} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ r_{n1} & \cdots & r_{nj} & \cdots & r_{nm} \end{bmatrix}$$

In accordance with the above, the point of interest would lie in working out the combination of characteristics that would maximize the relationships shown, while optimizing the remainder of the information available, both on requirements (exogenous information) and on the product's own characteristics (endogenous information).

2.1. Exogenous information (consumer voice)

Details of requirements serve as a starting point in establishing what clients expect from the new product. However, in the decision model it is necessary to consider all information that allows the data available to be differentiated and aids in decisions relative to what "best" characteristics are to be incorporated into the product from this perspective.

For the purposes of the model put forward in this paper, information coming from outside the business is summed up in the following three variables:

a. The importance of the requirements or in other words "requirements of consumers, ponderated" (RCP_i). Not all requirements have the same impact or ponderation, that is, they do not meet equally the views on the new product that potential consumers have. Hence, it is essential to look first at the degree of importance of each requirement (g_i), this denoting the weight assigned by the clients to each of the needs or wants that they express. Similarly, in measuring this importance it is necessary to incorporate information relating to the characteristics linked to each of the requirements (r_{ij}). This is because a requirement is not solely important in itself, but will depend upon the characteristics that affect it and the degree of relationship it has with these features.
   Such a joint evaluation permits a value to be established for the requirements which are weighted as a function of the importance allocated to each by the consumers (g_i) and of the characteristics with which any given requirement is related and the strength or degree of this relationship (r_{ij}):

$$RCP_i = \sum_{j=1}^{m} r_{ij} \times g_i$$

b. Competitive evaluation or external benchmarking (t_i). An external competitive analysis tries to establish from the viewpoint of present or potential consumers a measurement of the extent to which each requirement is fulfilled, as compared with competing products. This evaluation yields as a result the rate of improvement or distance between the current state of affairs and the situation considered to be the objective to be attained: $t_i = m_i - b_i$ where: m_i is a goal for requirement RC_i and b_i is current value of requirement RC_i for the firm's product.
   Although in the model proposed information about the weightings of requirements and about comparative evaluation are incorporated separately, there is the possibility of establishing a joint valuation for the two together to act as a measurement of the impact or weighting (w_i) each requirement has from an external perspective. For this purpose the following operation would yield a value:

$$w_i = RCP_i \times t_i$$

c. Correlation between requirements (γ_{ij}). This correlation permits the highlighting of possible incompatibilities or effects of reinforcement among the requirements put forwards by clients:

$$\begin{bmatrix} \gamma_{11} & \cdots & \gamma_{1j} & \cdots & \gamma_{1n} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ \gamma_{i1} & \cdots & \gamma_{ij} & \cdots & \gamma_{1n} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ \gamma_{n1} & \cdots & \gamma_{nj} & \cdots & \gamma_{nn} \end{bmatrix}$$

2.2. Endogenous information (engineer voice)

This section attempts to analyze information relating to those aspects which may affect the selection of possible characteristics for inclusion in the new product on the basis of information supplied from within the firm, which in the model being proposed would be captured by the following four variables:

a. Importance of features or "characteristic aspects, ponderated" (CAP_j). The attributes of the new product translated into characteristics that can be measured in it should be quantified from a twofold perspective: the weight that each has as a function of its relationship with the requirements noted by clients and the importance assigned to these requirements from the viewpoint of future potential consumers. Thus, and similarly to what was done for requirements, the first step to be taken is to quantify each characteristic on the basis of the two aspects mentioned. This quantification is to be carried out as follows:

$$CAP_j = \sum_{i=1}^{n} r_{ij} \times g_i$$

b. Competitive evaluation or internal benchmarking (B_j). This attempts to evaluate product characteristics by comparing each of the design requirements with those of competitors, except that this time it is the business itself that does the evaluation and determines its positioning in accordance with studies of the competition undertaken. The measurement for this variable is then established as follows: $B_j = m_j - b_j$, where: m_j is a goal for characteristic CA_j and b_j current value for characteristic CA_j to be incorporated into the firm's product.

c. Technical difficulty (C_j). This variable measures the level of difficulty in technical terms of fulfilling the objectives, defined for each of the design characteristics of the product. This difficulty may be established from the point of view of putting the feature into practice or alternatively in terms of the cash cost associated with including each of the characteristics.
Likewise, as a function of the weighting of the characteristics and of an evaluation of the technical difficulty each presents, it is feasible to calculate an intermediate variable showing up the "impact of the technology of characteristic aspects" ($ITCA_j$): $ITCA_j = CAP_j \times C_j$

d. The correlation between characteristics (δ_{ij}). The possible characteristics to be developed in the new product that are noted within the business are not always independent one from another, but may have synergies or negative relationships among themselves that it is necessary to take into consideration when the time comes to favour certain of them over others. This may be represented by means of the following matrix:

$$\begin{bmatrix} \delta_{11} & \ldots & \delta_{1j} & \ldots & \delta_{1m} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ \delta_{i1} & \ldots & \delta_{ij} & \ldots & \delta_{1m} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ \delta_{m1} & \ldots & \delta_{mj} & \ldots & \delta_{mm} \end{bmatrix}$$

3. NPD and uncertainty: use of linguistic information

In the description of the problem of NPD given in the previous section it is pointed out that there is a need to operate with variables based on information gathered from very diverse origins. In some cases, it is the business itself that provides the data, while in others it is necessary to have recourse to information from outside the firm, obtained either from its own consumers or from experts and even through carrying out market analysis.

These circumstances indicate the difficulty of rendering down into numerical form this information, since it is people who must express their judgements about the value to be assigned to it, and for most humans it is simpler to state their opinion in language terms. Similarly, because the information required affects the future, and by definition in the case of new products there is no knowledge of parallel situations that have occurred in the past, in most instances it will be very difficult to set a fully certain value on the information involved.

In the light of the above, two circumstances can be picked out which make it necessary to undertake an adaptation of the traditional model for developing new products so that it will be closer to real situations, at least in so far as it addresses the following:

- It should be recognized that the most natural way of gathering information is through the language normally utilized by human beings and that the expressions in day-to-day natural language are imprecise. Thus, an attempt should be made to set up mechanisms that take this situation into account and try to operate with this information without the need to transform it into numerical form.
- It should be recognized that it is difficult to express information relating to the future in numerical terms. Hence, preference should go to those mathematical tools which permit estimates to be used.

The restrictions noted above imply the necessity of tackling the problem under conditions of imprecision and uncertainty [22]. This is the source of the interest this paper has in using a set of language terms that will permit the gathering of information both from outside the firm (clients) and from its own internal resources (engineers). It is also necessary that clients can express their opinion in the friendlier expression dominion for them, which implies to unify this information in an only dominion of expression. There are diverse proposals although most of them assumes loss of information in this process.

Before this perspective it is tried to use the model proposed in [13] like representation model. These authors raise a model of representation of the linguistic information with 2-tuples that allows to operate with the linguistic information without risk of loss of information. Thus it will be possible to use the necessary operators of aggregation and comparison in the model for a representation of this type.

The model for representing linguistic information that uses as its basis of representation a pair of values or 2-tuple [14], is a language representation model founded on the concept of symbolic translation. It may be defined as follows: Let $S = \{S_0, ..., S_g\}$□a set of language items, and $\beta \in [0, g]$ a value obtained by a symbolic method operating with linguistic information. The symbolic translation of a linguistic term s_i is a number whose value lies in the interval $[-0.5, +0.5]$ and encapsulates the "difference in information" between a quantity of information expressed by the value $\beta \in [0, g]$, obtained through a symbol operation, and the nearest whole number value, $i \in \{0, ..., g\}$, indicating the index of the linguistic label (s_i) that is closest in S.

The representational model based on the concept of symbol translation utilizes as its basis for representation 2-tuples, (τ_i, α_i), where $\tau_i \in S$ and $\alpha_i \in [-0'5, 0'5)$, with τ_i being a linguistic label and α_i the number expressing the value of the distance from the original result β to the index of the closest linguistic label (τ_i) in the set of language items S, that is, its symbol translation.

Use of a representation as explained above requires conversion of classic linguistic labels into their equivalents as a 2-tuple. For this purpose, with $s_i \in S$ being a language item, its representation by means of an equivalent 2-tuple is obtained through the function θ:

$$\theta : S \rightarrow (S \times [-0'5, 0'5))$$
$$\theta(s_i) = (s_i, 0) \, / \; s_i \in S$$

Thus, starting from a numerical value β, $\beta \in [0,g]$ obtained from a symbol operation it is possible to work out the language 2-tuple that would express the information equivalent to β by using the following function:

$$\Delta : [0, g] \;\rightarrow\; S_x \, [-0'5, 0'5)$$
$$\Delta(\beta) = (s_i, \alpha), con \;\begin{cases} s_i, & i = round\,(\beta) \\ \alpha = \beta - i, & \alpha \in [-0'5, 0'5) \end{cases}$$

where *round* is the usual rounding operator, s_i represents the label whose index is closest to β and α is the symbolic translation value.

The workings of the function Δ can be stated as follows: if it is supposed that there is a symbol aggregation operation on labels with values in the set of linguistic items $S = \{s_0, s_1, s_2, s_3, s_4, s_5, s_6\}$ and that the result of this aggregation is a value $\beta = 2.8$, the representation of this information through a linguistic 2-tuple is Δ (2.8) = (s_3, -0.2), as shown Fig. 2.

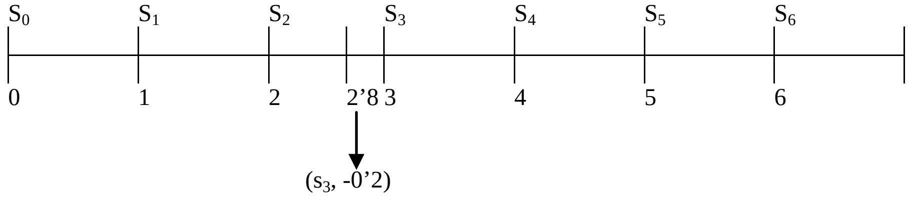

Fig. 2

Thus, with a view to generalizing the process whereby a 2-tuple yields its numeric value, it is possible to take the line that if $S =\{s_0, \dots , s_g\}$ is a set of language terms and (s_i, α) a linguistic 2-tuple, it is feasible to obtain the equivalent numerical value $\beta \in [0, g]$ by means of the following function Δ^{-1}:

$$\Delta^{-1} : S x [-0'5, 0'5) \quad \rightarrow \quad [0, g]$$

$$\Delta^{-1} (s_i, \alpha) = i + \alpha = \beta$$

Furthermore, it seems clear that the model representing information that is based on 2-tuples provides a set of operators allowing the operations of comparison, negation and aggregation. Similarly, it may be noted that use of the Δ^{-1} function defined above allows a linguistic 2-tuple to be converted into a number in the interval $[0, g]$, so that it becomes simple and easy to adapt any numerical aggregation operator to combine language 2-tuples.

Moreover, in those decision areas where the evaluations used to resolve problems arising lie in the domain of language, situations occur in which these evaluations do not utilize the same set of labels, but belong to different linguistic sets, with differing graininess and/or semantics. In other words it is common for the information required to handle a problem to come from several sources, and possible for each of them in turn to have different grades of uncertainty and so need to use sets of labels of varying graininess, that is, be defined within a context of multiple linguistic textures. Hence the fuzzy language approach has a major limitation when it comes to carrying out processes of aggregation with multi-grained language information: there exist no standard procedures for normalization nor operators for aggregation for this sort of information. This need arises in most management problems and in the NPD problem.

For this purpose, the model proposed here starts from the initial suggestion made by [13], who considered the existence of linguistic contexts of varying graininess, which they termed "linguistic hierarchies". These are governed by a series of rules and conditions, so that operations on multi-texture linguistic information evaluated in these contexts permit its unification into a single domain of expression without loss of information.

Linguistic hierarchies are composed of a set of levels, in which each level is a set of language items with a different graininess from that of the other levels in its hierarchy. Each level of a hierarchy can be written as:

$$L\ (t, n(t))$$

where t is the number indicating the level of the hierarchy and $n(t)$ represents the graininess of the linguistic set of level t.

Levels within a hierarchy are ordered by their graininess, that is, for two successive levels t and $t+1$ it will hold that $n(t+1) > n(t)$.

In accordance with the above, a linguistic hierarchy (LH) can be defined as the union of all levels t:

$$LH = \bigcup_t l\,(t,n(t))$$

To analyze the construction of a linguistic hierarchy, keeping in mind that its hierarchic order is given by the change in graininess of texture in the sets of linguistic items on each level, the start point is a set of labels S on the domain U on level t, such that:

$$S = \{s_0 ,..., s_{n(t)-1}\}$$

with s_k language items in the set S and with $k = 0, \dots n(t) - 1$.

To construct a linguistic hierarchy, the definition of S can be extended to permit the existence of various sets of linguistic items, each with a differing graininess on each level. For this, the parameter $n(t)$ is introduced into the definition of a set of labels, representing the graininess of the set on the level t where it is defined:

$$S^{n(t)}\ \{s_0^{n(t)} ,..., s_{n(t)-1}^{n(t)}\}$$

By way of an illustration, if a linguistic set is used with a triangular, symmetrical and uniformly distributed assignment function having an odd graininess value, in Table 1. the graininess needed for each linguistic set on level t is shown, depending on the value $n(t)$ defined on the first level (3 and 7, respectively).

	L (t, n(t))	L (t, n(t))
Nivel 1	L (1, 3)	L (1, 7)
Nivel 2	L (2, 5)	L (2, 13)
Nivel 3	L (3, 9)	

Table 1.

In general, it can thus be seen that the set of terms on level $t+1$ is obtained from its predecessor as:

$$L\ (t, n(t)) \rightarrow L\ (t + 1, 2 \cdot n(t) - 1)$$

In Fig. 3 a diagram of linguistic hierarchies with 3, 5 and 9 labels is shown.

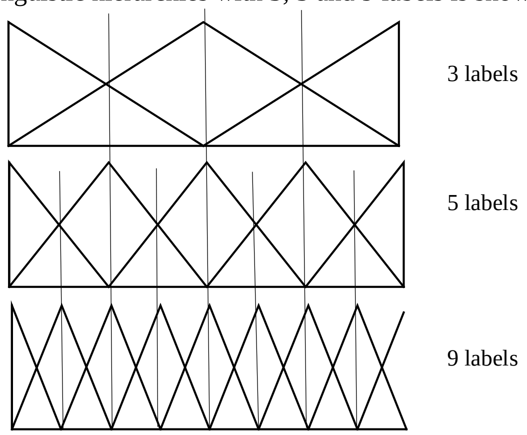

Fig. 3

Moreover, once the operations involved in the construction of a linguistic hierarchy have been described, it will be necessary to establish a function permitting transfer of linguistic information from one set of terms to another without loss of information. This requires definition of the passage from one level to those immediately above and below it, with the aim of thereafter generalizing the procedure. For this purpose, the function for transformation of a term from level *t* into a term on level *t+1* is defined as:

$$TF^{t}_{t+1} : l(t,n(t)) \rightarrow l(t+1, n(t+1))$$

$$TF^{t}_{t+1}(s_i^{n(t)}, \alpha^{n(t)}) = \Delta\left(\frac{\Delta^{-1}(s_i^{n(t)}, \alpha^{n(t)}) \cdot (n(t+1) - 1)}{n(t) - 1}\right)$$

For its part, the function for transforming a term from level *t* into one on level t-*1* is defined as:

$$TF^{t}_{t-1} : l(t,n(t)) \rightarrow l(t-1, n(t-1))$$

$$TF^{t}_{t-1}(s_i^{n(t)}, \alpha^{n(t)}) = \Delta\left(\frac{\Delta^{-1}(s_i^{n(t)}, \alpha^{n(t)}) \cdot (n(t-1) - 1)}{n(t) - 1}\right)$$

The generalization of the operations just quoted, with the aim of allowing transformations between terms from non-consecutive levels, can be attained by use of a recursive function based on the two functions given above. In this way, the recursive function for the transformation of a term from level *t* into one on level *t' = t+a,* with a $\alpha \in Z$ is defined as follows:

$$TF^{t}_{t'} : l(t,n(t)) \rightarrow l(t', n(t'))$$

• If |a| > 1 then $$TF^{t}_{t'}(s_i^{n(t)}, \alpha^{n(t)}) = TF_{t'}^{+\frac{t-t'}{|t-t'|}}\left(TF^{t}_{t+\frac{t-t'}{|t-t'|}}(s_i^{n(t)}, \alpha\alpha^{n(t)})\right)$$

• If |a| > 1 then $$TF^{t}_{t'}(s_i^{n(t)}, \alpha^{n(t)}) = TF^{t}_{t+\frac{t-t'}{|t-t'|}}(s_i^{n(t)}, \alpha\alpha^{n(t)})$$

The function for transforming terms between different levels in a hierarchy is idempotent, which guarantees transformation without information loss.

Moreover, the aggregation process consists of obtaining a value to represent the set of values it is desired to aggregate. The result of the process applied to a set of 2-tuples will itself be a 2-tuple. The resolution of this process may be approached by the utilization of numeric aggregation operators and their extension so they can work with linguistic 2-tuples, or through the application of symbolic aggregation operators to handle such 2-tuples.

If the variables have the same importance the operating average of 2-tuples can be used, that it is defined as:

$$\bar{x} = \Delta\left(\frac{\sum_{i=1}^{n} \Delta^{-1}(s_i, \alpha_i)}{n}\right)$$

The values obtained will permit the establishment of the best alternative within the given domain of expression. This is because, even if they may coincide in respect of the value of the label defining them, it is possible to pick out which is closest to each label from among the range.

4. The choice of actions to be taken in NPD with linguistic information

In accordance with the comments about the NPD problem, it is essential to set up a mechanism to permit determination of the optimal combination of characteristics to be incorporated into a new product on the basis of the information contained in variables relating to the requirements expressed by potential clients and to that provided by the firm's own design engineers, expressed in linguistic terms.

In order to show the treatment to apply to the variables of the model which is exposed in the second section, it has been developed an example that facilitates the understanding of the linguistic data processing with the representation in 2-tuples.

4.1. Exogenous information (consumer voice)

The first variable (importance of the requirements $\widetilde{R}\widetilde{C}\widetilde{P}_i$) is established by the relations between these and the characteristics as well as by the importance that the possible consumers grant to each one of them. With the operative analyzed, the information about these two variables can be established in two sets of different labels (as much in its granularity as in its semantics). It will be necessary to add the value of both variables in order to apply the model.

In first term the aggregation process precise of a normalization mechanism that allows to unify the multigranular linguistic information in an only dominion of expression.

In order to verify the operatively of this treatment of linguistic information we have chosen to use two sets of labels with maxima granularity and different semantics:

- Ponderation factor of the requirements: l(1,5)
- Relations between requirements and characteristics: l(2,9)

The set of linguistic terms of the ponderation factor $\{s_0^5, s_1^5, s_2^5, s_3^5, s_4^5\}$ is the equivalent one to the linguistics labels: Nil (s_0^5), Of_Little_Importance (s_1^5), Middling (s_2^5), Important (s_3^5), Very_Important (s_4^5), this is {N, OLI, M, I, VI}.

For the relations between requirements and characteristics, the set of linguistic terms $\{s_0^9, s_1^9, s_2^9, s_3^9, s_4^9, s_5^9, s_6^9, s_7^9, s_8^9\}$ is equivalent to: Extremely_Weak (s_0^9), Very_Weak (s_1^9), Quite_Weak (s_2^9), Weak (s_3^9), Moderate (s_4^9), Strong (s_5^9), Quite_Strong (s_6^9), Very_Strong (s_7^9), Essential (s_8^9), that is, {EW, VW, QW, W, M, S, QS, VS, E}.

If the set settles down like set of linguistic terms to unify this information in an only dominion l(2,9), by means of the function of transformation analyzed in the previous part, the values for the case of the ponderation factor of the requirements in the chosen dominion will be the following ones:

$$TF_2^1(s_0^5, 0) = \Delta^{-1}\left(\frac{\Delta(s_0^5, 0)\cdot(9-1)}{(5-1)}\right) = \Delta^{-1}(0) = (s_0^9, 0)$$

$$TF_2^1(s_1^5, 0) = \Delta^{-1}\left(\frac{\Delta(s_1^5, 0)\cdot(9-1)}{(5-1)}\right) = \Delta^{-1}(2) = (s_2^9, 0)$$

$$TF_2^1(s_2^5, 0) = \Delta^{-1}\left(\frac{\Delta(s_2^5, 0)\cdot(9-1)}{(5-1)}\right) = \Delta^{-1}(4) = (s_4^9, 0)$$

$$TF_2^1(s_3^5, 0) = \Delta^{-1}\left(\frac{\Delta(s_3^5, 0)\cdot(9-1)}{(5-1)}\right) = \Delta^{-1}(6) = (s_6^9, 0)$$

$$TF_2^1(s_4^5, 0) = \Delta^{-1}\left(\frac{\Delta(s_4^5, 0)\cdot(9-1)}{(5-1)}\right) = \Delta^{-1}(8) = (s_8^9, 0)$$

Thus, the calculation of the importance of the weighed requirements will be possible. The process is the following one:

RC_i	$i = 1,2,\ldots,n$	Number of requirements
CA_j	$j = 1,2,\ldots m$	Number of characteristics

r_{ij} relation between requirement *i* with characteristic *j*

g_i importance of the requirement *i*

A function is defined $g(r_{ij}, g_i)$ to establish the measurement of the importance of each requirement *i* on the basis of the relation that it has with the characteristic j and the importance assigned to this requirement *i*, as shown below:

$$g(r_{ij}, g_i) = MIN(r_{ij}, g_i)$$

It is possible to use the minimum operator because the relations and the importance of the requirements are established in the same dominion.

It will be precise to add the result obtained to apply function *g* to each characteristic in order to know the relation between each requirement *i* and all the characteristics. As it is known the aggregation procedures can be diverse. If the variables have the same importance the operating average of 2-tuples exposed in the previous section can be used like operator to add the information of the importance of each requirement based on all the characteristics.

The results which have been obtained after this process will give a measurement of the importance of the weighed requirements that, by means of the use of the representation in 2-tuples, allows to establish a label for the same one, but without losing the information since it stays by means of the value of symbolic translation.

As shown in this part, the information related to the rest of variables of the model will follow the same procedure: representation by means of 2-tuples, aggregation by means of the operating average and representation of results by means of approximation to the nearest label to the original dominion, by maintaining the information with the object of the later operative by means of the second component of 2-tuple.

Thus, the benchmark of the requirements ($\tilde{t}_i$) will need to operate with the linguistic information related to the current situation of the company and the situation in which the companies which it is desired to compete with are. The dominion of expression of both variables will have to be unified in the chosen dominion *[l(1,9)]* for all the model, given the later necessity of aggregation with the rest of variables.

The calculation of the goal or distance is made by applying the operator of comparison of 2-tuples, so that the result provides an evaluation of the level of improvement in linguistic terms, to which 9 labels has been associated, whose information makes reference to the need to improve, and which are the following ones: Extremely_Negative, Very_Strongly_Negative, Strongly_Negative, Weakly_Negative, Practically_Zero, Weakly_Positive, Strongly_Positive, Very_Strongly_Positive and Extremely_Positive, that is {EN, VSN, SN, WN, PZ, WP, SP, VSP, EP}. Next and by homogeneity, the aggregation of this information is made by means of the application of the operating average of 2-tuples.

Finally, the inclusion in the model of the information about the correlation between requirements (γ_{ij}) will be made by unifying it with the rest of information, with the same procedure that in the previous cases.

4.2. Endogenous information (engineer voice)

The data obtained within the company can also be dealt with the representation in 2-tuples, as carried out with the external information.

Thus, the importance of the characteristics ($\widetilde{C}\widetilde{A}\widetilde{P}_j$) is determined by the relation between each one of them and the requirements and the importance of these ones, that is, the same information is used to weigh up the requirements but by analysing from the perspective of the characteristics.

The set *l(2,9)* was chosen to unify all the information processed by the model, reason why the importance of the characteristics will have to be expressed in this set.

This procedure is carried out just by applying function *g*, already defined, to establish the measurement of the importance of each requirement on the basis of the relation with all the characteristics and by adding the result, in this case from the perspective of each characteristic. The aggregation operator will be also the operating average for 2-tuples used in the previous case.

The results of the evaluation of the characteristics importance will be defined, therefore, in 9 labels, whose meaning has been mentioned previously. The evaluation has been made by means of the nearest linguistic label to the 2-tuple which establishes the importance. However, it is maintaining all the information by the second component of 2-tuple, so that the characteristics importance in its inclusion in the measurement of the quality of the solutions will be made with all the information.

The second variable, internal benchmarking ($\tilde{B}_j$) uses the information of the situation of the company regarding the development of the characteristics as well as the situation of the competition. Before coming to its comparison, will be precise to unify the information in the dominion chosen for the model *[l(2,9)]*.

The unified information allows to apply the comparison operator. The result will be in this dominion, after considering the use of the same linguistic labels that in the benchmark of the requirements.

Technical difficulty ($\tilde{C}_j$) is a variable which acts negatively on the desirability of inclusion of a characteristic in the optimum solution. For this reason, the adequacy function will include the complement of this variable. This information will be unified in the expression dominion of the rest of variables *[l(2,9)]*.

In a way analogous to the relationships in existence among requirements, correlations among characteristics ($\tilde{\delta}_{ij}$) may be negative. This is the reason that these relationships are fixed in the range [-1, 1], with the representation of the values associated with language variables being symmetrical within this range. However, the value set on the correlation between given characteristics depends directly upon the solution that is being evaluated, since it will reflect only the relationship existing between the characteristics that will be developed in the product, and these depend directly upon each solution.

The comments above permit an evaluation function to be established for the various combinations of characteristics that could be developed in the new product in the following way:

$$\tilde{F}_S = \begin{cases} \sum_{j=1}^{m} \left(\tilde{C}\tilde{A}\tilde{P}_j + \tilde{B}_j + \tilde{C}_j + \sum_{s=1}^{n} \tilde{\delta}_{sj} + \tilde{C}\tilde{A}_j^i \right) & si \quad CA_j \subset \quad S \\ 0 & si \quad CA_j \not\subset \quad S \end{cases}$$

where $\tilde{F}_S$ represents the goodness of solution *S*.

Finally, to establish the cost of the development of a characteristic, a numerical valuation is normally used. However, when there is uncertainty about the quantification of this variable, it will be possible to use the mechanisms to work with this uncertainty.

5. Conclusions

The importance that the New Products Development has in the survival of the companies widely is recognized. In more and more uncertain environments, an increasing competence, mature industries, demanding markets and constant technological advances, the companies find that the satisfying the needs of the consumers is not a strategic option but a strategic necessity. In fact, one of topics of business management more important and greater complexity is the voice of consumer management in the development and introduction of new products.

Even though traditional models recognize the necessity of working with qualitative information, the literature to date on the topic under study has not put forward any appropriate methodology for handling vague, fuzzy or linguistic information.

In the face of this limitation, the present paper tries to respond by the application of mechanisms permitting operations with linguistic information. For this purpose, the 2-tuple linguistic representation was presented. This representation is utilized for to build a model for NPD problem. It permits it to be demonstrated that this model overcomes the drawback described earlier, making it easy for the decision process to be carried out with linguistic information.

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