Mapping Product Innovation Profile To Product Development Activities – The I-DSM Tool

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Abstract— The quality of the decisions during the design phase of a product development process is strongly connected with the assessment of the product, process and organizational innovation dimensions. The developed methodology addresses the three dimensions, using 30 innovation attributes, in order to obtain a product innovation profile through an innovation survey. An Innovation Design Structure Matrix Tool (I-DSM Tool) is used for mapping and analyzing the dependencies between the Innovation Attributes. Furthermore an Innovation Improvement Impact Value for each Attribute is introduced and an optimal improvement strategy is defined. Next the product innovation profile is mapped with the product development activities, in order to evaluate the effect of the proposed strategy to the activities cost and durations.

Keywords— Innovation Measurement, Benchmarking, Innovation Profile, Innovation Attributes, Design Structure Matrix

I. INTRODUCTION

Developing high quality innovative products more efficiently and effectively tops the competitive agenda for senior managers around the world. The rapid evolution of marketable technologies - a key source of competitiveness - is entirely dependent on a company’s ability to effectively manage its product development. Taken that every firm can be represented as a bundle of resources, skills and competencies [1], the effect of innovation is to transform a firm’s inner capabilities, making it more adaptive, better able to learn, to exploit new ideas.

This paper presents the Product Innovation Profile Methodology, which measures the innovative performance of a company and the I-DSM tool, which is a novel application approach of a Design Structure Matrix and aims at providing an optimum Innovation Improvement Strategy. Furthermore the proposed strategy is evaluated, in terms of it’s impact to the total duration and cost of the product development process.

II. THE PRODUCT INNOVATION PROFILE METHODOLOGY

All initiatives on improving the innovation within the organization in the past, have addressed ways of improving the product innovation process, through a wide spectrum of methods, techniques and tools without quantifying the degree of change of “innovativeness”. The innovation process is iterative in nature and thus, automatically includes the first introduction of a new innovation and the reintroduction of an improved innovation. This iterative process implies varying degrees of innovativeness [2]. The Product Innovation Profile (PIP) approach is a methodology, which is used to position an organization in terms of its level of product innovation maturity [3,4].

The PIP methodology addresses 3 axis of innovation:

1. The product axis: the renewal, enlargement and improvement of the range of products
2. The process axis: the establishment of new methods of production, design, supply and distribution
3. The management axis: the introduction of changes in management, organisation design, the working conditions and skills of the workforce

Product Innovation occurs when a new or improved product is introduced to the market. Process innovation is an adoption of new ways of making products or services. The innovation process is the combination of activities - such as market research, communication, design, process development and so on - which are necessary to develop and support an innovative product. There is a strong correlation between product innovation and process innovation. Process innovation may result in product innovation and similarly, product innovation may force process innovation. Organizational innovation follows these two dimensions. Since now innovation surveys discount the importance of role of organisation in innovation. They focus instead on the process of technology acquisition and sources of information for innovation.

Since now there are no initiatives or schemes, which have addressed all three dimensions, in a holistic approach to a company innovation and attempted to resolve them in order to determine their independency. Not in any case has the emphasis of the research been placed on ‘what is the value, level of the innovation within an organisation considering their products, innovation process and project management of the process?’.

The PIP methodology utilises ten attributes for each axis (Table I). The range for each attribute is between 0 and 4 having discrete fraction of 0.1. There is one question that corresponds to each innovation attribute in the survey. By resolving the above three axes values a PIP SCORE is obtained. This value represents the “innovationness” of the company in a specific sector (Fig. 1).
Table I
THE INNOVATION ATTRIBUTES (IA) OF EACH DIMENSION

<table>
<thead>
<tr>
<th>Product Dimension</th>
<th>Process Dimension</th>
<th>Management Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA(1) Market need</td>
<td>IA(11) Market appraisal</td>
<td>IA(21) Focus on feasibility studies</td>
</tr>
<tr>
<td>IA(2) Easy appeal to target groups</td>
<td>IA(12) Liaise with target groups</td>
<td>IA(22) Formal procedures to ensure dialogue with target groups</td>
</tr>
<tr>
<td>IA(3) Best use of technology</td>
<td>IA(13) Technology access</td>
<td>IA(23) Formal procedures for evaluating best use of technology</td>
</tr>
<tr>
<td>IA(4) Value for money</td>
<td>IA(14) Value and cost analysis</td>
<td>IA(24) Costing controls</td>
</tr>
<tr>
<td>IA(5) Standards compliance</td>
<td>IA(15) Compliance investigation</td>
<td>IA(25) Quality control procedures for standards compliance</td>
</tr>
<tr>
<td>IA(6) Original/novel solution</td>
<td>IA(16) Idea generation technique</td>
<td>IA(26) Maintenance of culture to ensure original/novel solution</td>
</tr>
<tr>
<td>IA(7) Offers improvements</td>
<td>IA(17) for improvement</td>
<td>IA(27) Measurable tests to determine improvement</td>
</tr>
<tr>
<td>IA(8) Delivers functional needs</td>
<td>IA(18) Processes for delivering functional needs</td>
<td>IA(28) Measurable tests to ensure functional needs</td>
</tr>
<tr>
<td>IA(9) Good aesthetic definition</td>
<td>IA(19) Design emphasis on good aesthetic definition</td>
<td>IA(29) Marketing and quality control procedures to determine good aesthetic definition</td>
</tr>
<tr>
<td>IA(10) Complies with IPR</td>
<td>IA(20) Ensure no breach of IPR</td>
<td>IA(30) Legal process control</td>
</tr>
</tbody>
</table>

Scoring on these 3 axes is at the heart of creating a replicable innovation register and benchmark. The approach itself focuses on using non-intrusive assessment and diagnostics methods and techniques to examine the organization and determine their level of innovation in respect of product and/or service development. The company’s current “position” is then evident together with the capability to set targets whereby the enterprise can improve such a score / profile and benefit from this initiative. Previous experience, piloting such techniques, indicates it is possible to offer a very fast track process - 2-3 days - to determine the register. Designing a framework for improvement of this scoring (ie. the targets) can be achieved within a single day (or less). Designing a framework for improvement of this scoring can either be very general and could be done within a single day, but its application is recursive and there are many dependencies. We propose the DSM approach to model the improvement phase, which can take more time but it can have high impact on the results.

So far more than 600 companies coming from a range of industrial sectors that include creative industries, electrical/electronic, fire and safety, footwear, plastics, ceramics and textiles, have participated in the PIP survey and their innovation profiles have been included in the database. The results indicated that the principles were sound and that the approach had great value because:

• An initial innovation register and profile is obtained
• A degree of change can be measured after intervention(s) (ie. implementation of attribute or property) against the original register and profile
• Registers can be established for companies of similar topologies and sectors and can be characterised as benchmarks for best practice.

The basic goal of the model is to improve the innovative performance of the company. In order to improve any of Innovative Attributes that construct the Innovation Profile of a company, a considerable amount of resources is needed, including special tools and techniques, special training, usage of experts or consultants, new cooperation’s, etc. Provided that resources are usually limited to most companies, an optimal improvement selection strategy must be developed. For this reason a new Tool, the Innovation Design Structure Matrix tool is introduced.

II. THE DESIGN STRUCTURE MATRIX MODELING METHOD

The Design Structure Matrix or Dependency Structure Matrix (DSM) is a generic matrix-based framework for information flow analysis [5]. DSM is a useful tool for analyzing highly complicated dependencies, inclusive of feedback and coupled tasks. The last decade the method received increased attention and is applied to the product development process as a powerful management tool [6-7].

DSM is constructed by listing all the system elements on the rows and in the same order on the columns resulting in a square matrix. Next, dependency relations between the system elements are represented in the matrix. These dependency relations can be indicated by
symbol (e.g. X), or by a numerical value which expresses the level of dependency between the elements (Fig. 2).

Based on the type of the elements that are included, the DSM can be categorized to [8, 9]:
1. Component-Based or Architecture DSM: Based on components and/or subsystems and their relationships.
2. Team-Based or Organization DSM: Based on people and/or groups and their interactions.
3. Activity-Based or Schedule DSM: Based on activities and their information flow and other dependencies.
4. Parameter-Based (or Low-Level Schedule) DSM: based on design decisions and parameters, systems of equations, subroutine parameter exchanges, etc.

This paper proposes a novel application approach of the DSM methodology, based on the Innovation Attributes that construct the Product Innovation Profile of a Company.

II. A STRATEGY FOR IMPROVING INNOVATIVE PERFORMANCE

The basic goal of the I-DSM (Innovation Design Structure Matrix) tool is to improve the innovative performance of the company, which is assessed by the Product Innovation Profile methodology. In order to improve any of the Innovation Attributes that construct the Product Innovation Profile, a considerable amount of resources is needed. These resources are usually limited, so an optimal improvement selection strategy must be developed.

Statistical analysis in the PIP database indicated strong correlation between the three innovation dimensions. For example high level of correlation was shown between the management and process axis (Fig. 3). The results show that in general higher mean scores in one category tend to result in higher mean scores in the others for a particular company, i.e. a high management score tends to result in a high product and process score for a company. This can be rationalized. In general companies who are highly innovative in all three areas of product, management and process. This makes sense as a highly innovative management system in a company is likely to affect and push through to other company areas making it innovative as a whole. This can be used to support the assumption that if the product score is low, the management is likely to be low and the process low/medium. Further statistical analysis showed also various levels of correlation between the individual Innovation Attributes.

In addition groups of product development experts, categorized to company sectors according to the PIP methodology indicated dependencies between the Innovation Attributes (Fig. 4). An element in row i and column j, indicates the Dependency of the Innovation Attribute i from the Innovation Attribute j, D(i,j). The Innovation Attribute Scores are included in the diagonal. This dependency matrix is not symmetric, i.e. by improving the IA(i) may effect the IA(j), but the opposite reaction is not always valid. For example by improving IA(16) “idea generation technique” may have a strong positive effect to IA(2): “easy appeal to target groups”, but this can not be claimed for the vice-versa effect. Furthermore Innovation Attributes from the Management axis, have stronger effect to the Innovation Attributes of the other two axes.

By improving a specific Innovation Attribute, IA(i), a new Innovation Attribute Innovation Score, IS'(i) is obtained. There are cases where, by improving a specific IA, a chain reaction that effects all other Innovation attributes that are strongly connected with the IA(i) is emerged. That means that the Innovation Scores of the related Attributes can also be improved. For this reason an Innovation Improvement Impact Value for each Attribute is introduced. The I-DSM tool aims at indicating the Innovation Attributes that have the highest Innovation Improvement Impact value to the total Innovation Profile Score.

The Improvement Impact value, II(i) of an IA(i), tends to capture the following observations in a mathematical form:
1. There is no improvement impact value to an IA that has the highest Innovation Score (4).
2. The II(i) is highly dependant on the degree of improvement of the IA(i).
3. For each IA(i) there is an improvement capacity, IC(i) of its Innovation Score:
   \[ IC(i) = 4 - IS(i) \]. An IA with high improvement capacity is easier to improve than an IA with low improvement capacity.

4. The II(i) of an IA(i) is higher when the depending IAs have higher dependency values.

5. If the IS(i) is lower than the IS(j) then there is no improvement impact to the IA(j).

This way by improving the score of an IA(i) from IS(i) to IS'(i), the II(i) can be defined as:

\[ II(i) = \text{new value} - \text{old value} \]

B. References

Number citations consecutively in square brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]. Do not use “Ref. [3]” or “reference [3]” except at the beginning of a sentence:

“Reference [3] shows ... .”

Number footnotes separately in superscripts. Place the actual footnote at the bottom of the column in which it was cited. Do not put footnotes in the reference list. Use letters for table footnotes (see Table I). IEEE Transactions no longer use a journal prefix before the volume number. For example, use “IEEE Trans. Magn., vol. 25,” not “vol. MAG 25.”

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Capitalize only the first word in a paper title, except for proper nouns and element symbols. For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [6].

C. Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have already been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, ac, dc, and rms do not have to be defined. Abbreviations that incorporate periods should not have spaces: write “C.N.R.S.,” not “C. N. R. S.” Do not use abbreviations in the title unless they are unavoidable (for example, “IEEE” in the title of this article).

D. Equations

Number equations consecutively with equation numbers in parentheses flush with the right margin, as in (1). To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Use a long dash rather than a hyphen for a minus sign. Use parentheses to avoid ambiguities in denominators. Punctuate equations with commas or periods when they are part of a sentence, as in

\[ A + B = C. \]
Be sure that the symbols in your equation have been defined before the equation appears or immediately following. Italicize variables (T might refer to temperature, but $T$ is the unit tesla). Refer to “(1),” not “Eq. (1)” or “equation (1),” except at the beginning of a sentence: “Equation (1) is ... .”

E. Other Recommendations

The Roman numerals used to number the section headings are optional. If you do use them, number INTRODUCTION, but not ACKNOWLEDGMENT and REFERENCES, and begin Subheadings with letters. Use one space after periods and colons. Hyphenate complex modifiers: “zero-field-cooled magnetization.” Avoid dangling participles, such as, “Using (1), the potential was calculated.” Write instead, “The potential was calculated using (1),” or “Using (1), we calculated the potential.”

Use a zero before decimal points: “0.25,” not “.25.” Use “cm,” not “cc.” Indicate sample dimensions as “0.1 cm $\times$ 0.2 cm,” not “0.1 $\times$ 0.2 cm.” The abbreviation for “seconds” is “s,” not “sec.” Do not mix complete spellings and abbreviations of units: use “Wb/m$^2$” or “webers per square meter,” not “webers/m$^2$.” When expressing a range of values, write “7 to 9” or “7-9,” not “7~9.” Spell units when they appear in text: “…a few henries,” not “…a few H.” If your native language is not English, try to get a native English-speaking colleague to proofread your paper. Number each page at top, right corner: “1 of 3,” “2 of 3,” etc.

IV. DISCUSSION

Use either SI (MKS) or CGS as primary units. (SI units are strongly encouraged.) English units may be used as secondary units (in parentheses). This applies to papers in data storage. For example, write “15 Gb/cm$^2$” (100 Gb/in$^2$).” An exception is when English units are used as identifiers in trade, such as “3.5-inch disk drive.”

Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity that you use in an equation.

V. CONCLUSION

Finally, you are responsible for language as editors will not check it. Do a spell and grammar check. This is available in Word. If English is not your native language, get a professional proof-reader to help if possible.

The word “data” is plural, not singular. The subscript for the permeability of vacuum $\mu_0$ is zero, not a lowercase letter “o.” In American English, periods and commas are within quotation marks, like “this period.” A parenthetical statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.) A graph within a graph is an “inset,” not an “insert.” The word “alternatively” is preferred to the word “alternately” (unless you really mean something that alternates). Use the word “whereas” instead of “while” (unless you are referring to simultaneous events). Do not use the word “essentially” to mean “approximately” or “effectively.” Do not use the word “issue” as a euphemism for “problem.”

Be aware of the different meanings of the homophones “affect” (usually a verb) and “effect” (usually a noun), “complement” and “compliment,” “discreet” and “discrete,” “principal” (e.g., “principal investigator”) and “principle” (e.g., “principle of measurement”). Do not confuse “imply” and “infer.”

Prefixes such as “non,” “sub,” “micro,” “multi,” and “ultra” are not independent words; they should be joined to the words they modify, usually without a hyphen. There is no period after the “et” in the Latin abbreviation “et al.” (it is also italicized). The abbreviation “i.e.,” means “that is,” and the abbreviation “e.g.,” means “for example” (these abbreviations are not italicized).

ACKNOWLEDGMENT

The preferred spelling of the word “acknowledgment” in American English is without an “e” after the “g.” Use the singular heading even if you have many acknowledgments. Avoid expressions such as “One of us (J.Q.A.) would like to thank ... .” Instead, write “J. Q. Author thanks ... .” Sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page.
REFERENCES


