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A Multicriteria Decision Model for the Evaluation and Selection of Technologies in a R&D Centre

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Abstract: R&D Centres play a key role in the technology development process of industries, and therefore in their competitive strategies. They have responsibility in the identification, selection, acquisition, development and transfer of technology. Among these activities, the successful selection of new technologies is becoming a highly critical and complex challenge in the Technology Management Process. The problem of succeeding in the selection of new technologies is, from the methodological side, linked to heterogeneous key factors (technological, economic, human, and organisational). Many approaches deal with it by means of Multiple Criteria Decision Making (MCDM) techniques and tools. Nevertheless, most of the works are related to the selection of technologies in industrial cases and very few works have been found in the bibliography related to R&D Institutions and, in particular, Technological Centres. A model for the evaluation and decision about one or several technologies based on the MIVES (*Modelo Integrado de Valor para Evaluaciones de Sostenibilidad*) method is proposed. Introducing the motivations for using this method, after a review of the most used MCDM methods, and describing the structure of the model and the preliminary key parameters and relations among them. The proposed model is oriented to it's application in the manufacturing sector, observing the particularities of the sector in the selection of the critical factors related to technology, R&D Centre and Industry.

Key words: Technology Selection, R&D Centre, MCDM, MIVES, Technology Management.

1. Introduction

The main objective of this research work is to develop a methodology for the evaluation and selection of new technologies in a R&D Centre. The need of a special approach for the case of R&D Centres is based on the position and role of these entities in the Technology Development Process chain. The key premise is that the success in the selection, and further development of a technology, is not only dependant on the characteristics of the technology itself and on the capabilities of the centre, but also, in a significant proportion by the factors related to the industrial receptors of the technology and the relationships between the R&D centre and them.

The proposed model tries to provide an integrated approach in which the critical factors of the technology, the R&D centre and its potential industrial customers (final receivers of the technology) and their interrelations, are evaluated. The model must provide the option of selecting among several candidate technologies, for its application during strategic planning processes and also for making the decision in the adoption of a single technology, to be applied in daily, non-systematic situations. This paper introduces the relevance of the addressed

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problem, based on a deep literature review, makes a revision of the most applied Decision Making Methods, and selects MIVES (*Modelo Integrado de Valor para Evaluaciones de Sostenibilidad*) method as the basic tool for development. After this selection, the basic structure of the model is presented with the proposed application methodology. The key paramenters that configure the model are selected based on their significance in the literature review. Further refinemet must be perfomed, as introduced in the methodology description.

2. Technology Development and R&D Centres

Research, Development and Innovation activities are considered a key factor to ensure competitiveness and sustainable socioeconomic development (Phaal *et al.,* 1995). This significance is observed both in the most developed countries and in developing countries or emerging economies, (Guan *et al.,* 2009).

The process of technology maturation is being conditioned by the speeding up of industrial and economical activities, requiring significantly shorter development times and maximum effectiveness and efficiency in the complete development chain, form the identification to the implementation (Clausen *et al.,* 2013). This concern is also noticeable in the Public Administration Policies, in the case of European Commission support Programs (H2020), under the epigraph “Valley of Death”, fostering strategies and instruments to close the gap between research and market-society (De la Concha, 2014).

2.1. The Role of R&D centres

R&D centres are present almost in all the stages of the technology development chain: starting with the fundamental research, in collaboration with universities, proceeding to the development and demonstration of technology suitability in labs and pre-industrial prototypes, up to the transfer to their industrial partners, making use of different mechanisms: collaboration projects, licensing, generation of start-ups, transfer of researchers. This position is key for the technology evaluation and selection strategies and activities of the centres, making necessary an integral evaluation of the environment factors to ensure the suitability and success potentials of a technology. In the method presented in this paper this leads to an integrated three areas evaluation.

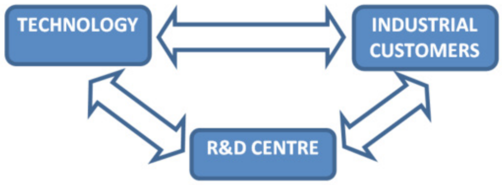

Figure 1. Basic scheme of interrelations in the technology selection model.

2.2. The manufacturing sector

Although the proposed selection model is intended to be applicable in any technological and application sector, manufacturing sector has been particularly observed in the selection of key parameters that characterize the scenario (represented in Figure 1).

The importance of manufacturing sector has been widely addressed in the last decades, playing a fundamental role in the generation, support and traction of economic and social development (Dobbs *et al.,* 2012). The direct relation between the economic development and the weight of the sector in the GDP of the countries has been reported, both for developed countries (Kaldor, 1967) and developing countries (Felipe *et al.,* 2014).

This prominence varies as the economic growth of a region evolves, from the quantitative to a more qualitative role. In developed mature countries, other economic sectors such as services take the leading position, being the upper limit of the manufacturing weight in the GDP establish in a band between 25 and 35 %. However, even in that situation manufacturing is key actor, providing the equipment and technologies needed to keep the leading position of the advanced economies, and sustaining challenges in social and environmental areas.

Public Administrations are fostering Policies, Programmes and Instruments to support an advanced manufacturing sector as the motor for the current and future social competitiveness and sustainability, positioning the technological development as the cornerstone of these strategies.

3. Technology selection

3.1. Technology Management

Assumed the relevance of the Technology Management Process for the competitiveness of industries and societies, Gregory (1995) formulated one of the most accepted definitions of the process: "Technology management addresses the effective identification, selection, acquisition, development, exploitation and protection of technologies needed to maintain a market position and business performance in accordance with the company's objectives", setting up the five main activities that configure the process.

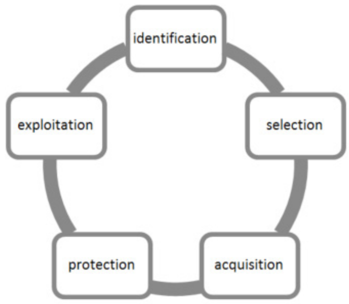

Figure 2. Technology Management process phases (Gregory, 1995).

Moreover, the process of Technology Management is not understood as an isolated activity, but as an integrated process in the strategy of any Company, in an integrated view with strategic and operative aspects (Phaal *et al*., 1998). Also in the phase of technology evaluation and selection, these integral criteria should be observed.

From these five activities this work is focused in the Technology Selection as one of the most critical, in particular for a mature sector, such as Manufacturing, and at the same time is one of the activities least systematically approached in R&D Institutions. The literature review contains numerous works about Industry and Public Administrations, but very few about R&D Centres.

3.2. Technology Selection and MCDM Methods

Technology selection is been a matter of numerous research works, resulting in families of methods, in some cases combining the identification and selection activities. Table 1 collects some of the most representative families of methods and tools:

Table 1. Technology Selection Methods.

Method	Description and References
Cost Benefit Analysis	Applied for selecting particular technologies in industry. Technology Pyramid Value (TVP) (Tipping *et al.*, 1995), Strategic Technology Assessment Review (STAR) (McGrath and MacMillan, 2000), System Wide Benefits Value Analysis (SWBVA) (Ordoobadi and Mulvaney, 2001) , Technology Balance Sheet (Hartman, 1999)
Impact Analysis	Very used in the evaluation of technological areas, within the strategies of Public Administrations and large Industrial and Technological Corporations. Among the tools used are Cross-Impact Analysis, Delphi (Dalkey and Helmer, 1963), Screening and Positioning Models, Integrated Impact Assessment, Ethical Technology Assessment.
Analysis of Scenarios	Widely adopted in different management fields. Diffenbach (1981) developed a three-step approach: formulation, scenario compatibility and compatibility assessment. Winebrake and Creswick (2003) combined AHP and Perspective Based Scenario Analysis (PBSA). Banuls and Salmeron (2006) proposed the Scenario Based Assessment Model (SBAM) which combines AHP, Cross-Impact Method (CIM), and Delphi.
Roadmapping	Management and Planning tool. Developed by Motorola to improve the alignment between technology and innovation (Willard and McClees, 1987). Extended to other large companies such as Phillips, RoyalMail, General Motors, Lockheed Martin, Erickson and British Telecom. Phaal, Farrukh and Probert (2000) estimated that 10% of manufacturing companies had used the technique.
Surveillance, monitoring and evaluation methods	Patent Analysis is widely used as a parameter for monitoring the impact of a technology (Slowinski *et al.*, 2000, Grimaldi eta al., 2015). Rohrbeck *et al.* (2006) developed the Technology Radar, for the evaluation and selection of emerging technologies in three phases of progressive filtering.
Multiple Criteria Decision Models (MCDM)	Applied when the key factors are heterogeneous in nature and dimension. Analytical Hierarchy Process (AHP), (Saaty, 1980) is the most extended, and enabler to develop adapted evolutions, such as ANP (Saaty, 1996) and MIVES (Viñolas *et al.,* 2009). Other methods are DEA (Data Envelopment Analysis) (Charnes *et al.,* 1978), TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) (Chen *et al.,* 1992), ELECTRE (Elimination et choix traduisant la realite) (Roy, 1968), PROMETHEE (Preference Ranking Organization Method Of Enrichment Evaluation) (Brans, 1982).

The MIVES method, introduced in table 1, is one of the youngest MCMD methods. It was developed and applied specially in Building sector. Methodologically it is based on a combination of AHP and Delphi, and one of its main attributes lays in the special value functions. These value functions, which can be defined individually for each key factor, provide a better, more accurate characterisation of each one of the factors, improving the power of the methodology. This characteristic and the novelty of applying it in manufacturing sector are the motivations to select it for this work. Therefore, MIVES will be the basis for the development of the technology selection method, with special emphasis in the definition of the proper value functions.

4. The proposed methodology and model for evaluation and selection of technology

The model proposed for the evaluation and selection of technologies in a R&D Centre is based on the application of MIVES method.

The methodology, following MIVES method, is structured in these steps:

1. Selection of critical factors and construction of the decision or hierarchy tree. This activity is carried out in two steps: in the initial one, the factors are selected from the literature review, in the second those factors are refined by the experts working group created for the generation of the model.
2. Creation of value functions to rate the critical factors in the lower level of the tree.
3. Factors weighting: the relative importance of each factor is assigned in relation to the others in the same level.
4. Evaluation of the alternatives (alternative technologies to be evaluated or "adopt-reject" in case of a single technology evaluation), obtaining the value index for each one.
5. Sensitivity analysis to evaluate the reliability of the model.

As mentioned, the model is based in AHP methodology, combined with working tools such as Delphi for the refining and weighting of factors. For this purpose a two level human working group is configured: a core group for the detailed work composed by experts from IK4-Ideko and geographically close R&D Centres and Industrial partners, and an extended group of international relevant contact persons, for some eventual contrasts.

4.1. Preliminar results

The preliminary version of the decision tree has been constructed. The selection of factors in this preliminary version is based on the extensive literature review about technology selection, especially in manufacturing sector, but not restricted to that sector. As mentioned, few works have been detected

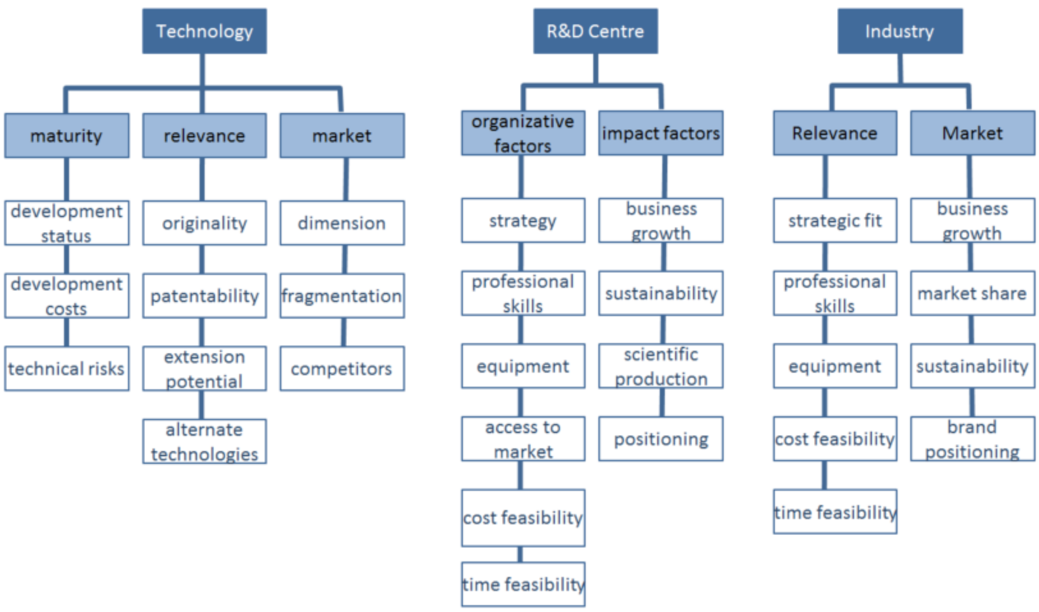

Figure 3. Hierarchy tree, based on the bibliography.

about R&D Centres, but the papers related to Industrial Companies, Universities and Public Institutions provided very useful information, with complementary approaches and criteria. The tree is structured in three areas: internal factors of the technologi(es) to be evaluated, characteristics of the R&D Centre and characteristics of the potential industrial receivers and implementers of the technology, as shown in Figure 3.

5. Conclusions and further work

Technology Selection is one of the key processes in Technology Management. Numerous research works can be found about the development and application of techniques to approach technology selection in industry, with a variety of orien-tations: strategy, impact, value chain, collaborations, capabilities and skills.

R&D Centres, due to their positioning and role in the Technology development chain, need to adopt an integral approach to the selection problem, including in their analysis not only their own internal factors but also the parameters related to the technology final receivers, their industrial partners or customers.

A MCDM methodology (MIVES) has been selected to tackle the challenge of developing a method for the selection of Technology in a R&D Centre.

Preliminary schemes of the model and hierarchy tree have been defined, based on the literature review. In the ongoing development phase, this tree will be refined, detailed and completed by the work of an expert's panel and finally the model will be completed with a quantification tool for the selection outputs.

Final validation of the methodology by appliying it to use cases will also be carried out.

References

Banuls, V.A., and Salmeron, J.L. (2006). A scenario-based assessment model - SBAM. *Technological Forecasting and Social Change, 74*(6), 750-762. https://doi.org/10.1016/j.techfore.2006.05.015

Brans, J.P., and Vincke, P. (1985). Note – A Preference Ranking Organisation Method. *Management Science, 31*(6), 647-656. https://doi.org/10.1287/mnsc.31.6.647

Charnes, A., Cooper, W.W., Lewin, A., Seiford, L.M. (1994). *Data envelopment analysis: theory, methodology and applications*. Massachusetts: Kluwer Academic Publishers. https://doi.org/10.1007/978-94-011-0637-5

Chen, S., Hwang, C., Beckmann, M., and Krelle, W. (1992). *Fuzzy multiple attribute decision making: methods and applications*. New York: Springer Verlag. https://doi.org/10.1007/978-3-642-46768-4_5

Clausen, T.H., Korneliussen, T., and Madsen, E.L. (2013). Modes of innovation, resources and their influence on product innovation: Empirical evidence from R&D active firms in Norway. *Technovation, 33*(6-7), 225-233. https://doi.org/10.1016/j.technovation.2013.02.002

Dalkey, N. C., and Helmer, O. (1963). An experimental application of the Delphi method to the use of experts. *Management Science, 9*(3), 458-467. https://doi.org/10.1287/mnsc.9.3.458

De la Concha, S. (2014). Horizonte2020, de la visión general a las oportunidades. XX y XXI Seminarios de Asesores de Proyectos de I+D de la Unión Europea.

Diffenbach, J. (1981). A compatibility approach to scenario evaluation. *Technological Forecasting and Social Change, 19*(2), 161-174. https://doi.org/10.1016/0040-1625(81)90013-5

Dobbs, R., Manyika, J., and Roxburh, C. (2012). *Manufacturing the future: The next era of global growth and innovation*. McKinsey Global, (November).

Felipe, J., Aashish, M., and Changyong, R. (2014). Manufacturing Matters... but it's the Jobs that Count. *Asian Development Bank Working Paper* No. 420.

Gregory, M.J. (1995). Technology management - a process approach. *Proceedings of the Institution of Mechanical Engineers, 209*(5), 347-356. https://doi.org/10.1243/PIME_PROC_1995_209_094_02

Grimaldi, M., Cricelli, L., Giovanni, M. Di, and Rogo, F. (2015). The patent portfolio value analysis: A new framework to leverage patent information for strategic technology planning. *Technological Forecasting and Social Change, 94*, 286-302 https://doi.org/10.1016/j.techfore.2014.10.013

Guan, J.C., Yam, R.C.M., Tang, E.P.Y., Lau, A.K.W. (2009). Innovation strategy and performance during economic transition: Evidences in Beijing, China. *Research Policy, 38*(5), 802-812. https://doi.org/10.1016/j.respol.2008.12.009

Hartmann, M.H. (1999). Theory and practice of technological corporate assessment. *Journal of Engineering and Technology Management, 17*(4), 504-521. https://doi.org/10.1504/IJTM.1999.002730

Kaldor, N. (1967). *Strategic Factors in Economic Development*. Ithaca: New York State School of Industrial and Labor Relations, Cornell University.

McGrath, R.G., MacMillan, I.C. (2000). Assessing technology projects using real options reasoning. *Research-Technology Management*, *43*(4), 35-49. https://doi.org/10.1080/08956308.2000.11671367

Ordoobadi, S.M., Mulvaney, N.J. (2001). Development of a justification tool for advanced manufacturing technologies-value analysis. *Journal of Engineering and Technology Management, 18*(2),157-184. https://doi.org/10.1016/S0923-4748(01)00033-9

Phaal, R., Paterson, C.J., and Probert, D.R. (1998). Technology management in manufacturing business: process and practical assessment. *Technovation, 18*(8-9), 541-589. https://doi.org/10.1016/S0166-4972(98)00026-1

Phaal, R., Farrukh, C.J.P., and Probert, D.R. (2001). *A framework for supporting the management of technological innovation*. Engineering Department, University of Cambridge, 1-14.

Rohrbeck, R., Heuer, J., and Arnold, H. (2006). The Technology Radar - An instrument of technology intelligence and innovation strategy. ICMIT 2006 *Proceedings - 2006 IEEE International Conference on Management of Innovation and Technology, 2*(September 2017), 978-983. https://doi.org/10.1109/ICMIT.2006.262368

Saaty, T.L. (1980). *The Analytic Hierarchy Process*. New York: McGraw-Hill. https://doi.org/10.21236/ADA214804

Saaty, T.L. (1996). *Decision Making with Dependence and Feedback, the Analytic Hierarchy Process*, (RS Publications: Pittsburgh, PA).

Slowinski, G., Stanton, S.A., Tao, J.C., Miller, W., and McConnell, D.P. (2000). Acquiring external technologies, *Res. Technol. Manag.*, *43*(5), 29-35. https://doi.org/10.1080/08956308.2000.11671378

Tipping, J.W., Zeffren, E., Fusfeld, A.R. (1995). Assessing the value of your technology, *Res. Technol. Manag., Vol. 38*(5), 22-39. https://doi.org/10.1080/08956308.1995.11674292

Viñolas, B., Cortés, F., Marques, A., Josa, A., and Aguado, A. (2009). MIVES: Modelo integrado de valor para evaluaciones de sostenibilidad. II Congrés Internacional de Mesura I Modelització de La Sostenibilitat, 1-24.

Willyard, C.H., McClees, C.W. (1987). Motorola's technology roadmap process, *Res. Manag., 30*(5), 13-19. https://doi.org/10.1080/00345334.1987.11757057

Winebrake, J.J., Creswick, B.P. (2003). The future of hydrogen fueling systems for transportation: an application of perspective-based scenario analysis using the analytic hierarchy process, *Technological Forecasting and Social Change, 70*(4), 359-384. https://doi.org/10.1016/S0040-1625(01)00189-5

