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Model for technological innovation integration and new product development in firms under innovation discontinuities

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Abstract

This article aims to contribute to a new planning policy in the development of innovative products. To do so, it presents a new modelling proposal to integrate technological innovation and new product development in a company of the traditional pewter sector in Portugal, under innovation discontinuities, carried out according to the following stages: Phase 1: Modelling of the information needs in product development process; Phase 2: Determining of technology integration dimensions to the product; and Phase 3: Evaluating the performance of technology integration dimensions to the product. A case study was conducted in a company of *traditional* tin sector in Portugal. The investigation was helped by the intervention of specialists. In order to reduce the subjectivity in the obtained results, the methods of Categorical Judgment Law, Artificial Neural Networks, the multi-criteria Electre III methods, compromised programming and Promethee II, multivariate analysis and the neuro fuzzy technology were used. The results were satisfactory, validating the present proposal.

Keywords: Modelling proposal, planning, integration, technological innovation, new product development, traditional pewter sector.

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1. Introduction

Recently, relevant changes have made organisational boundaries more fluid and dynamic in response to the rapid pace of knowledge diffusion (Abrahamson and Teece, 1986), [18], innovation and international competition [7]. This helps to reconsider how to succeed with innovation [18]. Thus, innovative companies make use of their capabilities to appropriate the economic value generated from their knowledge and innovations [12], (Teece, 1986). Therefore, the supply of innovative products is presented as a quality standard in the race for pressing demands. In this spectrum, the innovation process management becomes one of the greatest challenges. The literature refers to the product development process (PDP) and the technology development process (TDP) as the most relevant to the development of innovative products [14]. Thus, it is feasible that there is a concurrent and harmonic planning between these processes. Therefore, it is logical that the integration between these processes is fruitful, since the success of the innovation depends on the integration of them [14]. Technology and product have different cycles; the development projects face problems related to the incorporation or commercialisation of new technologies. The results to develop and use new technologies are time and efforts underestimated, besides developing technologies without having a pre-determined product, with different maturity degrees, which implies high costs, quality waste and inadequate deadlines.

Thus, this article aims to contribute to a new planning policy in the development of innovative products. To do so, it presents a new modelling proposal to integrate technological innovation and new product development (NPD) in a company of traditional pewter sector in Portugal, under innovation discontinuities, carried out according to the following stages: Phase 1: Modelling of the information needs in PDP; Phase 2: Determining of technology integration dimensions to the product; and Phase 3: Evaluating the performance of technology integration dimensions to the product. The companies of today are facing increased turbulence and complexity in the business environment. To meet these challenges, both the popular and the academic press are advising companies to focus their attention towards innovation in order to create and sustain competitive advantage. Here, we have lately seen increased attention towards innovation discontinuity. In fact, surprisingly, it is the discontinuities that can eventually have a game-changing impact on your business. The innovation discontinuity process consists of complex decisions. Many companies encounter internal and external barriers or inhibitors that get in the way of developing the right capabilities to support innovation discontinuity. Innovation discontinuity is not a one-time effort; it requires a continuously developing absorptive capacity to improve the overall capability of firms. A discontinuity is a temporary or permanent, sometimes unexpected, break in a dominant condition in society. This discontinuity is abrupt or gradual discontinuity. Abrupt discontinuity tends to manifest itself through events but these are usually connected to underlying processes. Discontinuity can also manifest itself in a more gradual manner and is a concept of transition for an elaboration of gradual discontinuity. A transition is a gradual, continuous process of change that leads to the transformation of a society, or a complex subsystem of society, over a period of at least one generation (Van Notten et al., 2005). Thus, this article is systematised into the following sections: 2 – Modelling: Steps and implementation; 3 – Methodology: Sample and Data Collection; 4 – Case study of multiple products: Implementation and underlying analyses; and 5 – Conclusion and implications.

2. Modelling: steps and implementation

This article aims to contribute to a new planning policy in the development of innovative products. To do so, it presents a new modelling proposal to integrate technological innovation and NPD in high tech environments. The research was developed over the literature specialised and applied in a company of traditional tin sector in Portugal, under innovation discontinuities, to confirm the modelling proposal and the theoretical excerpts. The research also had the intervention from specialists with knowledge about the investigated object. Next, the details from the modelling phases and stages were listed. Phase 1: Modelling of the information needs in PDP; Phase 2: Determining of technology integration dimensions to the product; and Phase 3: Evaluating the performance of technology integration dimensions to the product. The procedures are detailed below.

2.1. Phase 1: modelling of the information needs

This phase is structured according to the following stages and sub-stages: *stage 1*: definition of the characteristics of the products; *stage 2*: determination of the strategies of technological synchronisation used by companies in the development of products; *stage 3*: definition of the strategies of the innovation development; and *stage 4*: priorisation of the information needs.

Stage 1: The definition of the characteristics of the product presents the product's main characteristics.

Stage 2: The determination of the strategies of the technological synchronisation used by companies to manage the development of products. There are two strategies listed in the consulted literature: (1) simultaneous transference and (2) sequential transference.

Stage 3: The definition of the strategies of the innovation development consists of two strategies identified in the literature consulted: bottom-up and top-down.

Stage 4: Prioritising the need of information: This phase is structured into three stages: sub-stage (1): determination of the critical success factors (CSF); (2) determination of the information areas (IAs); and (3) prioritisation of the information needs starting from the crossing of CSF and the areas of information.

Sub-stage 4.1.: Determination of CSF: This phase is focused on determining the CSF, and is itself structured in two stages: (A) identification of CSF and (B) evaluation of CSF. (A) Identification: The identification of CSF is based on the combination of various methods: (a) environmental analysis (external variable: political, economic, legislative, and technology, among others); (b) analysis of the industry structure (users' needs, the evolution of the demand, users' satisfaction level, their preferences and needs and technological innovations); (c) meeting with specialists and decision-makers; and (d) the study of literature. (B) CSF evaluation: After their identification, the CSF is evaluated in order to establish a ranking by relevance. Here, the scale model of categorical judgments designed by Thurstone in 1927 has been adopted.

Sub-Stage 4.2: Determination of the Areas of Information: With the CSF having already been defined, the IAs are delimited with respect to the different CSFs.

Sub-stage 4.2.1: Determination of the activities of the PDP: In this sub-stage, the main activities realised during the PDP are identified. The following activities were performed according to the literature identified [3], [5], [6], [20]: development of the concept of product, elaboration of the product syllabus, preparation of the production, launching and after-launching of the product; determining strategies and product portfolio, elaborating and detailing the project syllabus, Determining technical and marketing merits of the project; Realisation of preliminary research to identify and analyse the market, technology and business characteristics, identifying and evaluating the consumer's claim by market sector (market research); defining the architecture and requirements of the product; carrying out product competitive benchmarking; defining functionalities of the Math product; generating assessment criteria of the concept of the product and carrying out tests of concept among others.

Sub-stage 4.2.2: Determination of TDP activities: In this sub-stage, the main activities of TDP based on Wheelwright and Clark [20], Clark and Fujimoto [3], Cooper [5], Clausing [4] are identified: (i) company strategic planning; (ii) determination of the technologic strategy; (iii) technology; (iv) consumer; (v) generation of ideas (vi) elaboration of project syllabus; (vii) future plans mapping; (viii) patent research; (ix) Identification of opportunities; (x) identification of the possibility of the idea in determined conditions through preliminary experiments; (xi) identification of the necessary resources and solutions for the identified failures; (xii) projection of platforms of products; (xiii) creation of QFD for technology (technological needs); among others. Consequently, the critical activities for integration are determined.

Sub-stage 4.2.3: Determination of the critical activities for integration: In this stage, the critical activities for integration of the technology to the product are defined. Integration must be understood as the set of activities or compatible practices between TDP and PDP [9], which aim at improving the application of knowledge to the products. Next, the IA global performances are evaluated according to the CSF.

Sub-Stage 4.3: Prioritisation of the information needs starting from the crossing of CSF and the areas of information: Again, these IAs are ranked by application of the same categorical judgment method of Thurstone in 1927 and put into relation with the CSF. At this moment, the following tools were adopted: (a) Multi-objective utility – multi-attribute, in this case compromise programming™, which mathematically represents the decision-makers' preference structure in situations of uncertainty; (b) selective, taken on account for the situation, Promethee II™ and (c) Electre III™.

2.2. Phase 2: determination of the dimensions of the integration of the technology to the product

In this stage, the dimensions of the integration of the technology to the product are defined [9]. The following dimensions present the integration of technology to the product: aspects, activities and time horizon [16]. Considers the other three dimensions of the integration: (1) strategic and operational synchronisation, (2) syllabus transference and (3) transference management. Finally, three basic elements are point out for integration [10, p. 1] synchronisation; (2) technology equalisation; (3) technological transference management. Iansiti [13] adopts knowledge as the main dimension for the integration of technology to the product. For this author, there will be integration if the knowledge generated by the area of R&D is applied to a new product. In this work, the knowledge is the dimension to be considered for the integration. This dimension is detailed ahead.

2.3. Identification and acquisition of knowledge

Initially, information topics which have been already identified will be elaborated, analysed and evaluated in order to be understood by the decision-makers during the formulation and the PDP and TDP. Following this, they will be reviewed and organised and validated by NPD and TDP specialists. Afterwards, relevant theories and concepts are determined. With respect to the acquisition procedures, different procedures of the process of acquisition represent the acquisition of necessary knowledge, abilities and experiences to create and maintain the essential experiences and areas of information selected and mapped out [8], (Wu, 2008). Acquiring knowledge (from specialists) implies, according to Buchanan [2], obtaining of information from specialists and/or from documented sources, classifying it in a declarative and procedural fashion, codifying it in a format used by the system and validating the consistence of the codified knowledge with the existent one in the system. Therefore, at first, the way the conversion from information into knowledge (Herschel et al., 2001) is dealt with should be understood by and useful for decision-making in technological innovation integration and NPD. First the information is gathered. The conversion (transformation) takes place as follows: first, the comparison of how the information is related to a given situation can be compared to other known situations is established; second, the implications brought about by the information for decision-making are analysed and evaluated; third, the relationship between new knowledge and that accumulated is established; and fourth, what decision-makers expect from the information is checked. Following this, the proceedings for the acquisition of theoretical background and concepts are dealt with. Such proceedings begin with the areas of information, one by one, where the concept and theory on which the performance is based of the actions (articulations) developed in those areas that allow guaranteeing the feasibility of new products development projects are identified. In other words, knowledge and theory are required to be known in order to ensure the success of NPD projects in that area. Then, the analysis of surveys in institutions about the job market for these institutions takes place bearing in mind the demands of similar areas studied in this work. As for the offer, we intend to search for the level of knowledge required by the companies and other organisations in those areas, as well as what concerns technical improvement (means) for the professionals. This stage determines the concept of knowledge to be taken into account on the development of this work. So, for the operational goals of this work, we have adopted them as the 'contextual information' and the theoretical framework and concepts.

2.4. Phase 3: assessment of the performance of the integration of technology process to the product

In this phase, the assessment of the performance of the integration of the technology process to the product is carried out. This procedure is realised based on the neuro fuzzy technology. The variables (knowledge) identified in the previous phase are input data for the neuro fuzzy modelling (in this phase). Thus, this phase focuses on determining the optimal efficiency rate (OERP) of the high-tech industries' product development and technology integration using neuro fuzzy modelling. It is a process whose attributes usually possess high subjectivity characteristics, in which the experience of the decision-maker is very significant. Thus, within this spectrum, there is the need for a tool that allows adding quantitative and qualitative variables that converge towards a single evaluation parameter [17], [21]. This model combines the neural networks and logic fuzzy technology (neuro fuzzy technology). Here, this model supports the product development and technology integration using neuro fuzzy modelling of high-tech industries, as it allows evaluating the desirable rate towards the acceptable performance of companies. The model shown here uses the model of Oliveira and Cury [17]. Based on the neuro fuzzy technology, the qualitative input data are grouped to determine the comparison parameters between alternatives. The technique is structured by combining all attributes (qualitative and quantitative variables) in inference blocks that use fuzzy-based rules and linguistic expressions, so that the preference for each alternative priority decision of the OERP of the high-tech industries' product development and technology integration, in terms of benefits to the company, can be expressed by a range varying from 0 to 10. The model consists of qualitative and quantitative variables, based on information from the experts. The neuro fuzzy model is described below.

3. Methodology: sample and data collection

The case study of multiple products was elaborated in a traditional segment of pewter in Portugal. The study was designed based on the literature and confirmed by the assessment of experts. The data collection was carried out using a scale/matrix assessment questionnaire. The technique used was the stated preference, taking into account that these methods work with the preferences of the decision-makers, revealed by the choice made among the alternatives selected from a set of real alternatives, or not. In this classification framework, the research interviews and consultations with the experts are highlighted. The experts issued their judgments through a scale questionnaire for the first external validation. Before applying the final collection instrument, a pre-test was conducted with experts to clarify whether the instructions were clear and objective; to verify that the questions were objective and without interpretation ambiguity; and to investigate possible comprehension problems by the experts on the expected responses. There were few adjustment suggestions. Next, a survey was conducted with experts, selected according to their technical–scientific criteria. The researcher regarded the new product project managers, experienced product planning personnel, innovation managers, engineers, designers, organisational managers, R&D managers, technology managers, planning, technological innovation and modelling managers. The phases and steps of the model were based on the following methods: (i) Thurstone's Law of categorical judgment psychometric scaling; (ii) multivariate analysis; and (iii) multicriteria: compromise programming, Promethee II, and Electre III and neuro fuzzy technology. Next, these procedures were detailed.

4. Case study of multiple products: implementation and underlying analyses

This section presents the verification procedures for the model. To demonstrate the feasibility and plausibility of the model, a case study is developed in light of an innovative experience in product and process, It was carried out by a multidisciplinary team consisting of designers, engineers and production technicians who worked together to develop new products that were intended to be introduced into the national and international market through a partnership between two institutions of higher education and a pewter product company in Portugal, whose traditional products developed by this company were in discontinuity of the innovation process. This project allowed combining additive manufacturing techniques and traditional processes of production of pewter components and the incorporation of other components in composite materials and other metallic alloys, allowing the development of innovative products in very short timeframes and contributing to an increase in the creation of business value. The multiple products investigated (parts ‘synesthesia’, effect on candlestick – wax, m. packaging, identification l. products, cover catalogue, candlesticks ‘cube’, candlesticks ‘lágrimas’, fruit bowl symbiosis and gutta, parts ‘unda’, fruit bowl ‘nirvana’, solitary spiral and bellevalia, parts cube and bateau, and parts spiral and synesthesia and others) in this research are innovative for the company and for the market. From the first initial sketches to the introduction of products in the market, it took little more than 5 months. The company introduced a whole new line of products on the market, more innovative, within a short period of time, through the adoption of new methods and NPD technologies, such as 3D CAD modelling, use of virtual ‘prototypes’, additive manufacturing technologies to obtain prototypes for viewing, conversion technologies and rapid manufacturing of tools for production of functional prototypes and final pieces. The study presents the PDP, the manufacture and placement on the market of pewter products aimed at innovating developed products and, simultaneously, it introduces new methods and product development technologies in the referred company. Thus, it was possible to know the details of the PDP of this company.

4.1. In summary: framework of the company and product characteristics

The modelling was applied in a company of *traditional* tin (pewter) sector in Portugal under innovation discontinuity. Thus, the data were gathered by consulting the partner–owners of the investigated company, through a structured questionnaire. In this investigation, it was possible to know details of the company’s PDP and TDP, in a way of verifying the practices conducted in the process of integration of the technology to the product. The research was based on multiple products (from the company) which succeeded well in the national market. It is believed that the product passed through the two fundamental stages identified in the theoretic excerpts: the PDP and TDP. The organisational structure of the company comprises the following areas: R&D, commercial, administrative/financial and administrative counselling. Based on the proposal previously presented, the following CSF from the company was identified: Market, Political/Legal; Economical and Financial; and Technical. The strategy of technological synchronisation adopted was the sequential technology transfer. At first, the technology was developed, then the product. After some experiments were conducted with the selected pieces, the need of some adaptations in the technology was verified. At this moment, the existing synchronisation between the processes becomes the simultaneous technology transfer for during the adaptation of the technology and activities such as appearance and performance tests were also realised. Besides, this case allowed identifying a time of 2 years, more than which the chance is smaller for the product project team and technology to share the results of the project. Thus, it is assumed that if the projects were realised with a time difference of 2 years maximum, they can be characterised as simultaneous synchronisation. Once the activities of PDP and TDP and the critical activities were defined, the next step was to define the concept of technology to be adopted in this application. The concept adopted has basis in the knowledge. The literature defines technology as the knowledge applied to obtain a product (a practical result). Afterwards, the procedure of transference of technology (knowledge) to the product was started. On one hand, it was the knowledge/technologies demanded by the product (PDP). On the other hand, it was the knowledge offered by technology (TDP). As aforementioned, the integration of the technology to the product has basis on the proposal of Iansiti [13], which has the knowledge as the main dimension of the integration of the technology to the product. The information area adopted in this application was R&D. The process of integration using the knowledge is shown as follows.

4.2. The process of integration of the technology to the product

The concepts adapted to knowledge are the theoretical bases and concepts and information of context. In this sense, the necessary knowledge to carry out the concept test was adopted; realisation of test and validation of the proposal of a new product; realisation of strength tests according to parameters; start of the pilot production; product launch and realisation of the effective production, among others. After being identified and acquired, the knowledge is evaluated, with the aid of the Method of Categorical Judgments of Thurstone [19] and artificial neural network (ANN). The results obtained some configurations of the ANN and compared with the CJT, it was observed that ANN 1 (see Figure 1) is the one that best approached the classification obtained for the CJT. ANNs, as well as Psychometric (CJL), was restricted only to the specialists' decisions in projects of raised subjectivity and complexity, needing other elements that consider the learning of new knowledge. However, it is interesting to highlight that the CJL method, as it considers a variable involving a high degree of subjective and complexity and because it works with probabilities in the intensity of preferences and considers the learning of new elements of knowledge. Thus, it can be said that for typology of application, as presented here, it is sufficiently indicated. The integration of these variables in the neuro fuzzy model results in a unique value which is the performance of the integration of the technology to the product. This enables to verify whether the procedure of integration was or not successful. The first 15 classified (CJL and ANN) variables were used. The results showed a great efficiency rate of integration of the technology to the product equal to 0.8756. This value corresponds to an average value for OERP. With this result, theOERP of product development and technology integration performance (0.8756) produced a better combination and interaction of knowledge dimensions (technologies) that converged towards a single parameter; it is feasible to assert that this combination of knowledge/technology. It is also plausible to state that, to some degree, there is efficiency in the management of those NPD planning in this category of companies. To illustrate this, assuming that the study-object company demonstrate the following OERPs (efficiency rate of integration of the technology to the product) (Figure 1).

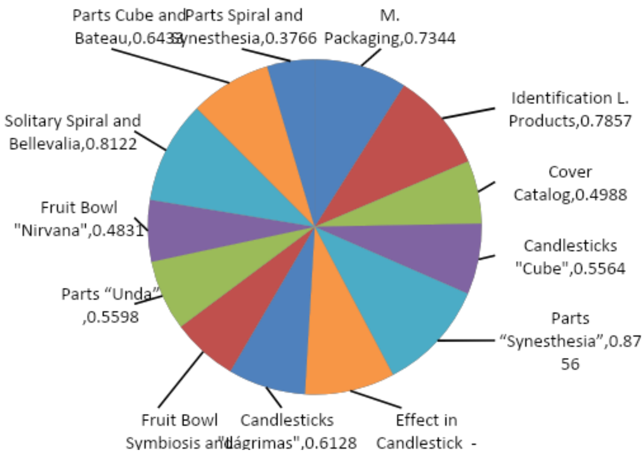

Figure 1. Efficiency rate of integration of the technology to the product

The best performance of the integration of technology process to the product part synesthesia (0.8756).

5. Conclusion and implications

This article aims to contribute to a new planning policy in the development of innovative products. To do so, it presents a new modelling proposal to integrate technological innovation and NPD in a company of traditional pewter sector in Portugal, under innovative discontinuities. This proposal focuses on highlighting unexplored questions in this complex design. However, it evidently does not intend to be a 'forced' methodology, but intends to render some contribution, even through independent courses of actions. By gathering cognitive elements, it can be seen that this strategy requires a priority dynamic, which is dependent on the initial state of training, on the concrete characteristics of the projects and cognitive problems that emerge during the practice, always putting in view new contents. This methodological support does not intend to be complete, but it is our intent to make it a generator of strategical elements for the development of new products development projects. Of the findings of the state of the art and state of practice, it is reasonable to state that this research is vulnerable to criticism. It is also underscored that the methodologies and technical basis of this modelling should undergo evaluation by a multidisciplinary team of specialists permanently and periodically, hence proposing possible additions or adjustments to these methodologies. And also replace some of the technical implementations used herein by others, in order to provide a similar role to verify the robustness of the model.

References

[1] E. Abrahamson, "Managerial fads and fashions: The diffusion and rejection of innovations," *Acad. Manage. Rev.*, vol. 16, no. 3, pp. 586–612, 1991.

[2] M. Buchanan, *Nexus: Small Worlds and the Groundbreaking Science of Networks?* New York, NY, USA: Norton, 2002.

[3] K. B. Clark and T. Fujimoto, *Product Development Performance: Strategy, Organization and Management in the World Auto Industry*. Boston, MA, USA: Harvard Business School Press, 1991.

[4] D. Clausing, *Total Quality Development: A Step-by-Step Guide to World-Class Concurrent Engineering*. New York, NY, USA: American Society of Mechanical Engineers, 1993.

[5] R. G. Cooper, "Managing technology development projects," *Res. Technol. Manage.*, vol. 49, no. 6, pp. 23–31, 2006.

[6] C. M. Creveling J. Slutsky, and D. Antis, *Design for Six Sigma in Technology \& Product Development*. Upper Saddle River, NJ, USA: Prentice-Hall, 2003.

[7] F. Damanpour, "Organizational complexity and innovation: Developing and testing multiple contingency models," *Manage. Sci.*, vol. 42, no. 5, pp. 693–713, 1996.

[8] C. Douligeris and N. Tilipakis, "A knowledge management paradigm in the supply chain," *EuroMed J. Bus.*, vol. 1, no. 1, pp. 66–83, Apr. 2006.

[9] A. Drejer, "Integrating product and technology development," *Int. J. Technol. Manage.*, vol. 24, nos. 2–3, pp. 124–142, 2002.

[10] W. Eldred and M. E. McGrath, "Commercializing new technology," *Res. Technol. Manage.*, vol. 40, no. 1, pp. 41–47, Jan. 1997.

[11] H. Eliufoo, "Knowledge creation in construction organisations: A case approach," *Learn. Org.*, vol. 15, no. 4, pp. 309–325, 2008.

[12] Z. Griliches, "Patent statistics as economic indicators: A survey," *J. Econ. Literature*, vol. 28, pp. 1661–1707, Jan. 1990.

[13] M. Iansiti, *Technology Integration: Making Critical Choices in a Dynamic World*. Boston, MA, USA: Harvard Business School Press, 1998.

[14] F. Johansson, *The Medici Effect, What Elephants \& Epidemics Can Teach us About Innovation*. Boston, MA, USA: Harvard Business School Press, 2006.
[15] J. S. Kurumoto, “Integra\c{c} \ {a} o Tecnologia e Produto,” M.S. thesis, Dept. Prod. Eng., Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil, 2009.
[16] D. Nobelius, “Linking product development to applied research: Transfer experiences from an automotive company,” *Technovation*, vol. 24, no. 4, pp. 321–334, 2004.
[17] R. L. M. Oliveira and M. V. Q. Cury, “Modelo neuro-fuzzy para escolha modal no transporte de cargas,” M.S. thesis, Dept. Eng. Transp., Inst. Militar Eng., Janeiro, Brazil, 2004.
[18] D. J. Teece, G. Pisano, and A. Shuen, “Dynamic capabilities and strategic management,” *Strategic Manage. J.*, vol. 18, no. 7, pp. 509–533, Aug. 1997.
[19] L. L. Thurstone, *A Law of Comparative Judgment*. England: Psychological Review, 1927.
[20] S. Wheelwright and K. Clark, *Revolutionising Product Development*. New York, NY, USA: Free Press, 1992.
[21] C. Von Altrock, *Fuzzy Logic and Neurofuzzy Applications in Business and Finance*. Upper Saddle River, NJ, USA: Prentice-Hall, 1997.