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CRITICAL SUCCESS FACTORS AFFECTING EFFICIENT MANAGEMENT OF THE NEW PRODUCT IMPLEMENTATION PROCESS AT RESEARCH ORGANISATIONS

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Purpose: Identification and selection of a set of critical success factors for a research organisation based on the evaluation conducted by managers of new product development processes at such organisations. Determination of factors that are of the utmost importance at the pre-development stage (so-called fuzzy front-end stage) and verification of the obtained results based on the case study of a successful new product implementation.
Design/method/approach: First, desk research was conducted, followed by a survey and a case study analysis.
Conclusions: The adequacy of the identified set of factors was confirmed (applicability of 90% of the selected factors was recognised). A number of additional success determinants of the new product development (NPD) process were specified. The importance of planning, tactical and organisational measures taken at the fuzzy front-end stage of the NPD process was confirmed. The crucial importance of identifying and verifying NPD process critical success factors was demonstrated.
Research limitations/implications: Possibility to expand the set of critical success factors for a research organisation, verification of the adequacy of the developed set based on other cases and types of technological solutions.
Practical implications: The study can serve as a reference for research organisations that want to verify the reasons for the success or failure of their implementation processes.
Social implications: The study can contribute to the implementation of standards and good practices concerning the NPD process implementation, which are directed at social participation and consideration of social needs during the processes of innovation development and implementation.
Originality/value: The study addresses the needs of teams involved in NPD processes, both at research organisations and in companies. The article provides important guidance to managers of NPD processes. It offers a comprehensive overview of critical success factors and identifies a set of good practices to improve the efficiency of the NPD process.

Keywords: critical success factors, CSF, new product development, NPD, commercialisation, research organisation.

Category: scientific article, case study.

1. Introduction

The generation of innovation ideas, i.e. the invention of new or improved solutions or discovery of alternative fields of use, may seem to be a crucial element of all new product development (NPD) processes at research organisations. However, in practice, this is only one of many milestones an organisation must reach to successfully commercialise its solutions. Research organisations that wish to maintain their competitive advantage and actively market innovations must be properly equipped to identify and verify critical success factors (CSFs) throughout the product development life cycle. The knowledge of the NPD process success factors may be particularly useful for R&D project managers and it can help them effectively plan the work of individual teams and make the right decisions about the implementation of innovative undertakings (even at an early stage), which are often crucial to the success of the entire project.

The literature discusses many impediments to the new product development process. The development of new innovations is most frequently hampered by technological barriers (Mazurkiewicz, Poteralska, 2016) and barriers of tactical nature (Mazurkiewicz et al., 2022) that adversely affect the cooperation between research organisations and end users of technological solutions as well as success of new product/technology implementation processes. However, many authors acknowledge that, in addition to identifying barriers to the NPD process, it is also possible to identify its critical success factors (Müller, Jugdev, 2012). The implementation of the NPD process may vary across industries and sectors. This is confirmed by relative abundance of publications centred around the identification of critical success factors for NPD processes per sector or product type (Almeida et al., 2020). This stems not only from external conditions (surrounding), but also from differences in the implementation of projects concerning development of new products based (to a greater or lesser extent) on new technologies. Additionally, there is a significant research gap – authors and practitioner fail to identify critical success factors for NPD processes at research organisations. This article assumes that critical success factors for NPD processes at research organisations and other entities differ due to the specificity of research organisations' operations and high innovativeness of the products they develop. Therefore, the article aims to select a set of critical success factors for research organisations, based on the evaluation conducted by managers of new product development processes at such organisations (institutes affiliated under the Łukasiewicz Research Network in Poland).

2. Method

For the purpose of this article, in order to determine critical success factors for NPD processes at research organisations, the "NPD process success" is defined as a full and timely implementation of a project, while maintaining at least minimum profitability (min. 5% gross margin).

To identify the set of CSFs for NPD processes, the authors conducted a literature review that covered articles published between 2010 and 2022 (they were selected using Google Scholar and Science Direct), as a result of which 35 most commonly discussed factors were indicated. The authors paid particular attention to the importance attached to each factor in individual market sectors. Factors selected as a result of the literature review were grouped and then assessed by 18 implementation project managers at research organisations. The survey (Google Forms) included factors of a universal nature (i.e. those that were most frequently listed with reference to the cases described) and factors indicated in the literature as crucial to the implementation of new technology-based products. The respondents represented 15 research organisations in Poland, including institutes affiliated under the Łukasiewicz Research Network. The survey was conducted with a view to selecting a final set of 10 critical success factors for NPD projects implemented by research organisations. The survey also included an additional question to identify those success factors that seem crucial, particularly with reference to the product pre-development stage, i.e. the fuzzy front-end stage. The selected success factor sets were then verified as part of the NPD process at a research organisation that ended with a successful implementation of a new product.

3. Literature review

New product development (NPD) can be defined as a set of measures taken by an organisation to develop a new, distinctive product tailored to the needs of end users. The NPD process is successful if end users want to try a new product and buy it again. Therefore, a team working on the development of an innovative product should check and consider how the market assesses the value offered by the product (Grunert, Trijp, 2014). The NPD process may be divided into three phases: fuzzy front-end (or project planning), product development, and commercialisation. (Gwo-Tsuen, Yuan, 2016). As regards practical implementation of NPD projects, a set of critical success factors (CSFs) is usually defined – critical success factors are considered the key elements an organisation needs to achieve certain goals (Pieterson, ICF, 2019). Critical success factors are also presented in the literature as conditions or variables that have a significant impact on the success of the project and real

impact on the success of the implementation of a product, provided that the measures taken by managers properly address such factors and ensure that they are present (Almeida et al., 2020).

Major NPD process success factors may be divided into the following three groups of factors: (1) technological factors (technology added value, cost reduction through technology use), (2) marketing factors (response to customers' needs, production time, profit, market share) as well as (3) management and commercialisation-related factors (price and margin management, additional investments in business model adaptation) (Walasik, 2013). Using the above-mentioned grouping, the factors are further classified in this article as technological, management and organisational (including marketing) factors.

The determination of critical success factors for an implementation project should also consider interdependencies between the factors identified. It is worth noting that the success of the NPD process depends on a number of factors, which can be interlinked, and that the evaluation of their importance should be holistic (Clarke, 1999).

The concept of the application of critical success factors for an NPD process at a research organisation is presented in Figure 1 below.

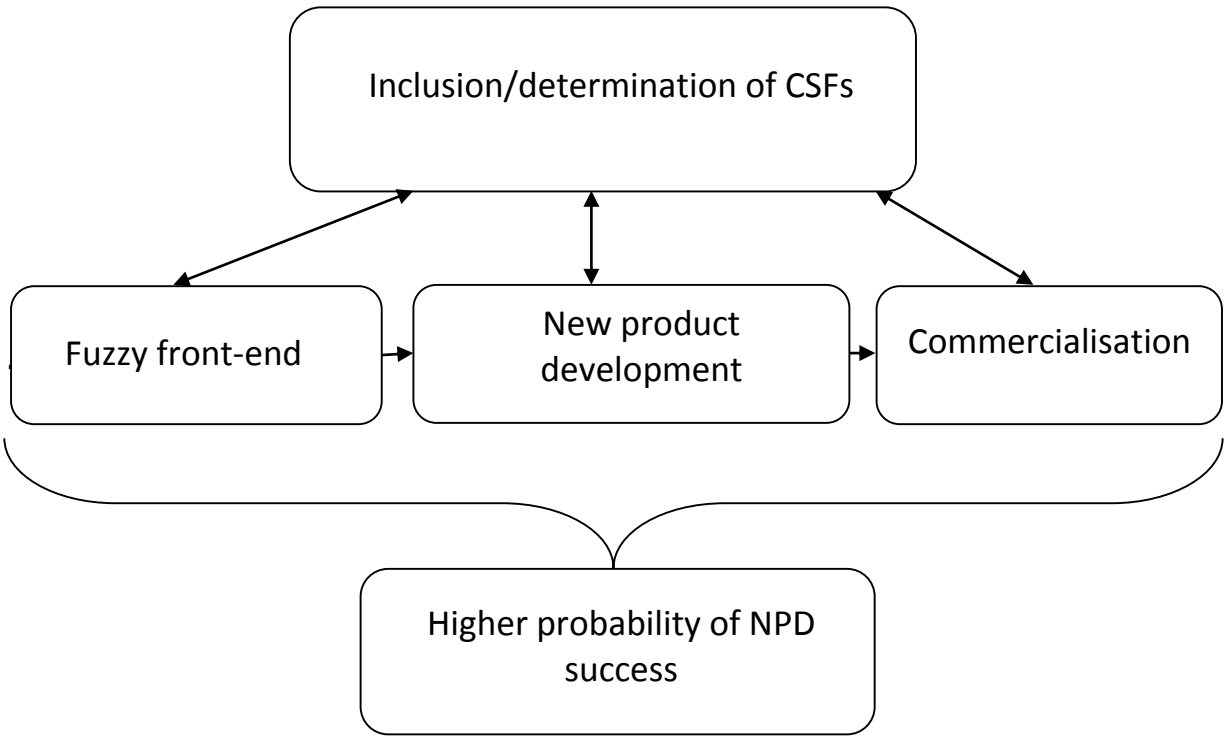

Figure 1. Visualised concept of increasing the probability of the NPD success by identifying and determining CSFs.

Source: Authors.

It should be noted that, while the correct identification of success factors at various stages of the NPD process can be crucial to the success of the implementation, the managers' impact on the creation of drivers may be limited; these factors may sometimes be completely beyond the control of the project team.

Table 1 presents the list of critical success factors identified through literature review per factor type.

Table 1.
Critical success factors in the NPD process identified in the literature

Factor type	CSF	Source
organisational	team experienced in NPD project implementation	Florén et al., 2018
	NPD process agility	Markham, Lee, 2013
	provision of effective communication channels	Lindhard, Larsen, 2016
	ensured flow of information in the IT system	Gal, Hadas, 2015
	structured process of new product development	Markham, Lee, 2013
	consideration of the risk and opportunity assessment at the planning stage	Dinu, 2016
	consideration of lessons learned in the planning phase	Lindhard, Larsen, 2016
	clearly specified roles and responsibilities	Dinu, 2016
	market analysis	Cooper, 2011
	creation of a business plan	Kornish, Hutchison-Krupat, 2017
	application of verified project and risk management methods	Stanley, Uden, 2013
	fixed priorities and resource allocation plans throughout the project	Buys, Stander, 2010
	establishment of focus groups to validate ideas	Cooper, 2011
	monitoring of financial and key performance indicators throughout the NPD process	De Souza, Lunkes, 2016
	ongoing monitoring of progress vs. budget	Frow, Marginson, Ogden, 2010
	product tailoring to individual needs of groups of customers	Walasik, 2013
management	engagement of mangers	Dwivedi, Karim, 2021
	compatibility of the project objective with the main objectives of the organisation	Florén et al., 2018
	clearly set goals and measurable milestones	Dwivedi, Karim, 2021
	engagement of experienced managers	Markham, Lee, 2013
	effective product portfolio management	Kester et al., 2011
	maintenance of reasonable headcount proportions in relation to the number of ongoing projects	Buys, Stander, 2010
	compliance with codes of ethics throughout the NPD process	Gal, Hadas, 2015
	motivating teams involved in the NPD process	PMBOK ,2013
	enabling team competence development in line with the project requirements	PMBOK, 2013
	evaluation of project-related benefits in relation to the organisation's strategic objectives	Breese, 2012
	provision of funds in relation to the individual elements of the business plan	Serra, Kunc, 2015
	periodic task progress reviews	Musawir et al., 2017
	implementation of the marketing strategy based on market segmentation	Walasik, 2013
	monitoring customer satisfaction throughout the NPD process	Walasik, 2013
technological	application of new IT achievements to collect and verify ideas from groups/communities	Cooper, 2011
	fair valuation of the benefits achieved through the use of technologies	Walasik, 2013
	application of modern Big Data analysis methods in the commercialisation process	Gunasekaran, 2017
	use of latest technological achievements to generate new product ideas	Wang, Zhang, 2020
	modification of business models with new technologies	Walasik, 2013

Source: Authors.

The literature review enabled the authors to identify a set of CSFs for the NPD process (Table 1). The articles reviewed discuss various NPD success factors, and, while most of them are of a universal nature and can be used with reference to many products and technologies, their importance differs depending on the project or market sector. To identify a set of critical success factors for NPD processes at research organisations, the authors used a survey method. The questionnaire was sent out to implementation project managers at Polish research organisations. The survey was conducted to identify a set of 10 CSFs of the utmost importance to the success of the NPD process and 5 most important factors that are essential at the fuzzy front-end stage of the NPD process.

5. Discussion of survey results

The respondents were asked to evaluate the importance of the 35 selected factors with reference to the NPD process at their organisations, and based on their feedback a list of 10 CSFs with the highest level of importance to the NPD process was complied. The respondents most frequently identified the following factors as important:

Organisational factors:

- clearly specified roles and responsibilities,
- creation of a business plan,
- monitoring of financial and key performance indicators throughout the NPD process; and
- product tailoring to individual needs of groups of customers.

Management factors:

- clearly set goals and measurable milestones,
- maintenance of reasonable headcount proportions in relation to the number of ongoing projects,
- provision of funds in relation to the individual elements of the business plan; and
- periodic task progress reviews.

Technological factors:

- fair valuation of the benefits achieved through the use of technologies; and
- use of latest technological achievements to generate new product ideas.

The compiled list was sent out to the respondents who were asked to identify factors that, in their opinion, are crucial at the fuzzy front-end stage of the NPD process. The respondents indicated the following factors:

Organisational factors:

- consideration of the risk and opportunity assessment at the planning stage,
- creation of a business plan; and
- product tailoring to individual needs of groups of customers.

Technological factors:

- application of new IT achievements to collect and verify ideas from groups/ communities; and
- use of latest technological achievements to generate new product ideas.

From the survey results it follows that the respondents indicated three factors most crucial, in their opinion, to the success of the entire project and its fuzzy front-end stage. They are as follows: (1) creation of a business plan, (2) product tailoring to individual needs of groups of customers, and (3) use of latest technological achievements to generate new product ideas. Additionally, the respondents identified factors falling into all of the above-mentioned categories (Table 1) – organisational, management, and technological – as crucial to the success of the entire implementation project. However, it is apparent that the organisational and technological factors outweigh the management factors in the context of the fuzzy front-end stage of the NPD process.

The obtained results show that all above-listed categories of factors (i.e. organisational, management, and technological) are crucial to the success of the NPD process. In turn, failure to consider the indicated factors in the NPD process may delay project implementation, increase its total cost or ultimately lead to project failure. Additionally, the CSFs indicated as crucial to the success of the NPD process are largely dependent on the measures taken by managers and project teams.

The obtained results also confirm the paramount importance of the organisational, planning and strategic activities to be taken at the fuzzy front-end stage of the NPD process, in the case of which particularly crucial are the factors of an organisational nature as well as the very conceptualisation of the new product. The respondents appreciated the great possibilities new technologies offer with reference to the formulation and validation of new product concepts at the initial stages of the NPD process.

The analysis also allowed the authors to conclude that the effectiveness of any NPD process depends not only on the use of an appropriate implementation model, but also on the identification of relevant CSFs – in the form of conditions and practices facilitating successful implementation of a new product. The CSFs may vary from process to process and their importance may depend on the specificity of a given sector, industry or environment in which the organisation operates. However, a set of universal factors may be identified based on the case study analysis of successful implementation projects in a specific market sector or industry. Moreover, many analysed CSFs are dependent on the adopted management and organisational standards. This means that organisations can acquire certain universal skills with reference to the identification and creation of conditions conducive to successful and agile implementation

of NPD processes. The fact that some organisations are characterised by greater agility and capability as regards new product implementation seems to confirm this. The analysis allowed the authors to conclude that organisations' agility in conducting NPD processes depends on the competences of managers as well as on the ability of teams to verify and create factors facilitating successful implementation of NPD projects (i.e. critical success factors).

The authors decided to verify the adequacy of the selected set of critical success factors on the basis of the implementation by a research organisation of a new product employing membrane technologies.

6. Case study-based verification of selected CSFs Implementation of products employing innovative membrane technologies

Membrane technologies allow the design and manufacture of filtration materials tailored to a manufacturing entity's specific needs and filtration conditions. The use of unique filtration materials characterised by resistance to the deposition of biological, organic and inorganic contaminants present in the filtered media helps increase the efficiency of wastewater treatment processes, reduce the cost of regeneration of used operating fluids, and extend the service life of filtration materials.

Membrane techniques include microfiltration, ultrafiltration, nanofiltration, and reverse osmosis. Solutions employing membrane technologies are scalable – the use of a modular system facilitates the expansion of a membrane filtration station, ensures continuity of the process, and makes it possible to automate the operation of the membrane filtration station and to connect the station with other machines included in the manufacturer's machine park. Membranes' life is short due to chemical and thermal impacts and, once worn out, membranes need to be replaced to ensure continuity of the process. Innovative membranes were developed at a research organisation to increase the effectiveness of the regeneration of wastewater generated by various industries. The concept of innovative filtration materials was developed by a team of researchers that verified and tested existing materials, technologies and their fields of use.

For the solution developed, a sales model (traditional model, including membrane production and provision of the design, testing, construction, assembly, and material replacement services) was identified as the preferred model of commercialisation. A licensing model was identified as a second possible model of commercialisation (applicable to potential breakthroughs as regards operating features or methods of filtration material regeneration). In the course of the NPD process, CSFs were identified as part of the developed go-to-market strategy.

Table 2.
Go-to-market plan for innovative products employing membrane technologies

Industries using membrane technologies	Manufacturers: Food industry			Coal mining industry	Tanneries
	Beverage manufacturers	Dairies	Manufacturers of other types of food		
Milestones	• reaching potential interested end users • need for filtration material regeneration/replacement • little experience in working on commissioned projects • no market recognition • competitors – monopolistic market				
Critical success factors:	**Measures taken – good practices:**				
OBJECTIVE 1. Comprehensive action plan	• development of business model canvas • schedule approval (in cooperation with employees) • determination of milestones and KPIs • determination of sources of financing for individual phases				
OBJECTIVE 2. Offer tailored to customers' needs	• compilation of a list of potential clients • interviews to determine whether the problem is significant enough for entrepreneurs to incur costs • consideration of the profitability of the subcontractor's market position – contacts with the existing supplier of solutions • determination of the preferred business models: design of solutions, development, subcontracting, projects				
OBJECTIVE 3. Information dissemination/educational activities	• development of promotional materials • traditional direct marketing methods (email, telephone, fairs) • launching a campaign that will help reach specific businesses (at a national level) through various communication channels • short educational video recording				
OBJECTIVE 4. Beating the competition	• analysis of competitors' offers, determination of price ranges • estimation of cost thresholds for standard undertakings (services price list)				
OBJECTIVE 5. Effective use of technologies	• determination of technological challenges – search for and investment in further technology development • search for inspiration (participation in industry events, membership of clusters, etc.) • patent applications for new technological solutions (protection of intellectual property)				

Source: Reports by the Commercialisation Department at Łukasiewicz Research Network – Institute for Sustainable Technologies.

7. Benchmarking conclusions

As part of the analysis of the case study of a successful implementation of the NPD process at a research organisation, the authors identified all three (3) factors indicated by the respondents as crucial to the entire process and to the fuzzy front-stage, i.e.: (1) creation of a business plan, (2) product tailoring to individual needs of groups of customers, and (3) use of latest technological achievements to generate new product ideas. The first stage of implementation was centred around organisational (preparing and approving, in consultation with employees, a detailed schedule) and planning (defining milestones and KPIs) tasks and around the preparation of business model canvas. This also means the identification of the

following success factors: (1) clearly set goals and measurable milestones, (2) monitoring of financial and key performance indicators throughout the NPD process, and (3) clearly specified roles and responsibilities. Additionally, sources of financing were identified for individual stages of the schedule implementation (KPI: provision of funds in relation to the individual elements of the business plan). This was followed by the verification of the final product concept and possible business models (as a result of market consultations and contact with a competitor). The authors also determined the profitability of the selected commercialisation/implementation models, indicated risks, and proposed mitigating measures (KPI: consideration of the risk and opportunity assessment at the planning stage).

In line with the generally applicable management standards, the implementation project progress was monitored on an ongoing basis – weekly team meetings and quarterly reports reviewed by a relevant Director for Research Development. (KPI: periodic task progress reviews). The implementation process was monitored continuously to identify potential issues and shortages of resources (also human resources) – appropriate corrective measures were taken (KPI: maintenance of reasonable headcount proportions in relation to the number of ongoing projects – here work planned in the project). The developed solutions were valuated and contracts were reviewed in cooperation with the Commercialisation Department, and then approved by the Managing Director (KPI: fair valuation of the benefits achieved through the use of technologies).

Therefore, it can be stated that in the case analysed, most KPIs determined in the survey as crucial to the implementation project were identified. Only the "application of new IT achievements to collect and verify ideas from groups/communities" factor relating to the use of online solutions (forum, digital platform) and possibilities offered by Big Data analytical tools with reference to the verification of potential customers' needs was not identified. Therefore, in the case analysed it seems that end users of the developed solution are clearly specified, which means that membership of industry clusters, participation in thematic events, and the use of account-based marketing are far more effective to reach relevant market segments than market consultations. A comprehensive look at the implementation methods also allowed the authors to identify success factors other than those selected during the survey: (1) implementation of the marketing strategy based on market segmentation, (2) engagement of experienced managers, (3) engagement of mangers, (4) consideration of lessons learned in the planning phase, and (4) team experienced in NPD project implementation.

8. Summary

The analysis allowed the identification and verification of a set of 10 critical success factors (CSFs) for NPD processes at research organisations. CSFs indicated by the survey respondents proved adequate in the case of the implementation of products employing innovative membrane technologies (9 out of the 10 CSFs indicated by the respondents were identified). The study can serve as a reference for research organisations that want to verify the reasons for the success or failure of their implementation processes. The survey also confirmed the cardinal importance of planning, tactical and organisational measures taken at the fuzzy front-end stage of the NPD process and the significance of the identification and verification of critical success factors for NPD processes at research organisations, which – based on the collected data – can develop standards, good practices, and relevant project implementation methods. The analysis may also provide the basis for future studies directed, for example, at expanding the set of critical success factors or verifying the adequacy of the presented set for various cases and types of technological solutions.

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