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Methods for Evaluating New Product Designs in the Portfolio Management Process in the Pre-Market Phases of Product Life Cycle

Abstract: The goal of the paper is to present methods for evaluating new product designs or projects in an integrated new product development process, as well as to propose a new method for optimising the value of new product portfolio management (NPPM) in the pre-market phases of product life cycle. The success level of a new product development strategy is significantly dependent on the degree of a company's competence, firstly in the implementation of the new product development process (NPDP), and secondly in the proper evaluation and selection of new product design concepts (executing the right project). In particular, the latter area of competence is related to the issues of portfolio management in the field of new product development. Thus, we are dealing here with a dynamic decision-making process – the Stage-Gate Process, according to which the design team is constantly updating, implementing and revising the current set of new product designs. Strategic decisions are also made on the allocation or reallocation of resources between active projects and whether to accelerate their implementation, change the assigned priority or abandon the project. This is a conceptual and methodological paper based on strategic management concepts and applications. It relates to new product development research. Methodological and research limitations identified in this work result from such circumstances as time and financial constraints or information availability. The scientific result of the article is a modified rank-resource method of evaluating projects/programmes in the NPDP funnel (a portfolio of projects at individual stages and gates of development process), containing both qualitative and quantitative criteria.

Keywords: new product management, portfolio methods, portfolio management, new products, new product development process

JEL: M11, M21, M31

1. Introduction

Globalisation processes, social changes and intensifying competition result in the need to use methods characterised by a high level of maturity that allow to organise new product development processes, reduce expenditures (work, money, and time) and manage risks (technical, market, economic, and social) at the same time providing new products that satisfy customer needs and compete in market segments, achieving business goals in the pre-market and market phases of product life cycle (Stark, 2018).

Portfolio management and known portfolio methods of assessing a strategic situation involve resource allocation to balance business risk reduction and sales or profit maximisation, with important decisions around the evaluation, prioritisation and selection of new products and innovation projects (those issues were described in many scientific papers and monographs, e.g.: M.M. Montoya-Weiss and R.J. Calantone (1994), R.G. Cooper, S.J. Edget, and E.J. Kleinschmidt (1999; 2000; 2001), A. Stabryła (2015), G. Gierszewska and M. Romanowska (2017), J.M. Rybicki (2000), as well as N. Lahtinen, E. Mustonen, and J. Harkonen (2021). This conceptual and methodological paper has its foundations in financial portfolio management and relates closely to new product development research and marketing product management, or a new product strategy. The organisational ability to manage new product projects portfolios connects portfolio management to key strategic organisational capabilities, including dynamic capabilities, and strategic flexibility. Hence, portfolio management should be viewed as a source of competitive advantage that supports organisational renewal (Kharat, Bhukya, 2018; Chagas Brasil, Eggers, 2019; Dąbrowski, 2022). A new product strategy links to new product development (NPD) through new product portfolio management (NPPM). This dynamic decision process addresses strategy implementation questions of identifying which new product ideas to pursue and their relative priorities. Despite the importance of NPPM in implementing a new product strategy, companies exhibit substantial performance-affecting differences. A potential source for such differences is the impact of managers' dispositional factors as a possible explanation of new product success or failure in the market (McNally et al., 2009; Cooper, 2017). Increasing the new product variety and expanding commercial offering create a challenge for companies in terms of keeping their new product portfolio profitable and managing it through the entire product life cycle (pre-market and market PLC). Effective new product portfolio management (NPPM) practices, supported by product structure considerations, may hold a key for new product profitability over its life cycle. Therefore, it is important to examine current practices and improvement possibilities in NPPM, including goals or targets and key performance indicators (KPI), by considering new product projects which will be introduced into product lines (Lahtinen, Mustonen, Harkonen, 2021).

The goal of the paper is to present methods for evaluating new product projects in the new product development process, as well as to propose a new method for optimising the value of a new product projects portfolio. The analysis here utilises the previous literature and proposes a modified rank-resource method of new product project evaluation. The article also demonstrates difficulties stemming from an inadequate definition of imperfect NPPM targets and KPIs over the product life cycle. The basic problem that is posed here concerns how to effectively allocate available resources to achieve goals set for a new product.

2. Pre-market stages and gates of product life cycle

Strategic approaches in the area of new product innovation are closely related to a sequential and concurrent or integrated process of new product development. The sequential approach was proposed by NASA in the early 1960s and is known as the PPP (Phased Project Planning) model, which is now called the PRP (Phased Review Process) model. Innovative enterprises may use a sequential (phased) or integrated (concurrent, simultaneous) new product development process (Cooper, 1994; Lambin, 2001).

The Integrated Product Development process (IPD) is a concept strongly focused on customer needs and company capabilities. The concept of an integrated new product development process, shown on the example of the Stage-Gate model, is presented in Figure 1.[1] The design or project team must know the strict criteria that need to be achieved at each stage/phase and work on a specific new product design until it is launched or withdrawn from the development process.

1 Various names are used for the concept of an integrated (concurrent) new product development process, e.g.: Stage-Gate Process, PDP (Product Delivery Process), NPP (New Product Process), and PLS (Product Launch System).

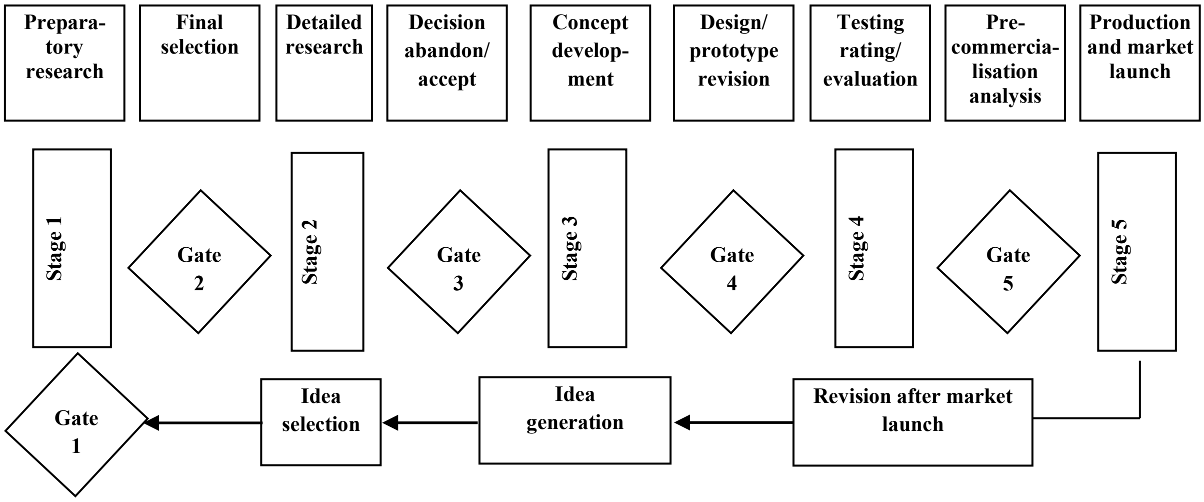

Figure 1. Phase-Gate method of integrated new product development (R.G. Cooper's method, the so-called Phase-Decision Gate)
Source: own elaboration based on Cooper, Edgett, 2009; Cooper, Kleinschmidt, 2010

Table 1 contains a description of the distinguished sets of main activities in the Stage-Gate process. In particular, this method highlights the integration of the product development process with strategic goals, improves organisational efficiency and creates a structure on the basis of which a new product concept and related technology are implemented. Integration should be considered in three following dimensions (Crow, 2015):

1) strategic integration – connects the decision-making process and forms of enterprise activity with specific, directional goals, which allows a given organisation to stand out in the market;
2) functional integration – combines various functional areas of the enterprise into a more effective and optimal whole;
3) logistics integration (supply chain) – extends the integration concept of product development beyond a given organisation and includes its customers, suppliers and other economic partners in the development process.

As a result of using an integrated new product development (IPD) process, more mature new product designs can be expected that can be transferred to the production phase and to the market with greater efficiency, using existing resources. Other effects are visible in greater flexibility and speed in adapting the company to developing new technologies and new customer needs.

Table 1. Description of the sets of main activities distinguished in the Stage-Gate process

Sets of Main Activities Distinguished in the Stage-Gate Process	
Gate 1 – idea selection: screening ideas derived from basic research and generated through the use of various creativity techniques with the participation of clients and other sources; an initial decision is made to allocate funds for further project work, signalling a trial commitment; qualitative criteria are used when making decisions: strategic importance, technical feasibility, the possibility of gaining a competitive advantage, and the level of attractiveness.	Phase 1 – preparatory (preliminary) research: defining market and technical goals of projects; project analysis (working time of the entire team from 2 to 4 weeks) includes preliminary market estimates (market size, market potential, possible market acceptance) and preliminary technical estimates (feasibility, technical parameters of production, factory production).
Gate 2 – final selection of ideas: includes a particularly rigorous selection of ideas, ideas must meet all evaluation criteria, methods are used to measure the synergy effect, market attractiveness and competitive situation, elements of the product's competitive advantage as well as development time and costs, production costs, rate return, potential turnover and profit.	Phase 2 – detailed research: the team defines the product and verifies the attractiveness of the project before significant resources are allocated to its further development; the following activities are carried out: identifying and analysing customer needs, defining the ideal product, competition analysis, concept testing, new product concepts are presented to potential customers, the level of acceptance is measured, technical assessment focuses on the feasibility of the project from an economic and technological point of view, factory assessment focuses on research on manufacturability, production costs, necessary investment outlays, an analysis of necessary legal undertakings related to acts, regulations, patents and other legal regulations is carried out, a detailed financial analysis including forecasts of discounted cash flow with a risk sensitivity analysis 'what if' is performed.
Gate 3 – abandon/accept decision: based on rigorous criteria, a decision is made to qualify the project to the next stage, the accepted project must meet the appropriate evaluation criteria, otherwise it is rejected.	Phase 3 – development of the product concept: the result of the activities undertaken at this stage is a product prototype prepared for laboratory testing; in parallel with technical work, appropriate marketing activities are carried out (work on the brand, packaging, promotion, etc.) and related to preparations for factory production of the product, market test plans are created, as well as programmes for introducing a new product into the market, along with production and production process management programmes, at the same time, the team updates financial and legal analyses.

Sets of Main Activities Distinguished in the Stage-Gate Process	
Gate 4 – design review (comprehensive): the team re-examines the attractiveness of the design; the following issues are resolved: does the prototype meet the quality and fashion requirements, is the developed concept of the new product consistent with its previously defined definition?	Phase 4 – new product testing and evaluation: at this stage, the team tests and evaluates the entire innovation process: the new product, production process, customer acceptance, potential economic results of the new product; the following activities are carried out in parallel: laboratory testing of product quality in specific conditions, research on purchase intentions, verification of the perceived value of the product and its functionality, pilot production of the new product, more precise determination of production costs, assessment of the efficiency of the production process, pre-test market, fundamental market testing, trial sales to measure buyer response, measuring the effectiveness of a new product launch plan, estimating market share and sales volume, revising financial analyses, and continuing economic evaluation of the new product based on more accurate cost and turnover data.
Gate 5 – analysis of the new product before commercialisation: the final decision is made to reject the new product or to fully commercialise it. The decision to commercialise makes it necessary to mobilise all the necessary resources needed to introduce the new product into the market; the key decision criteria are the state of preparation for full production and the readiness of all programmes to be introduced (production, marketing, and financial).	Phase 5 – full production and market introduction: implementation of previously prepared marketing, production and financial programmes begins; appropriate resources are secured and action plans are prepared in crisis and unpredictable situations. After a period of 6 to 18 months, the company reviews the new product after its introduction into the market. During this period, the team is responsible for the level of success of the new product. Then, the new product development process is finally completed and the interdepartmental team is dissolved. The new product becomes part of the product line offered by the company. The management reviews the results obtained from the sale of the new product and identifies its strengths and weaknesses. Depending on the market situation, another cycle of the new product development process may be initiated.

Source: own elaboration based on Cooper, 2014; 2017; Edgett, 2014

In the commonly presented NPDP model, the early and initial stages of the initial macrophase of the process include the formulation and development of ideas (the generation of ideas for a new product, the selection of ideas, and the development and testing of new product concepts), which will take a physical form in the course of subsequent phases and stages of work. In most industries, the decision to accept a new product concept and transfer it to subsequent phases of the NPDP results in significant financial consequences (see Figure 2).

NPDP is often viewed from a financial perspective, where cash outlays precede inflows. The figure above presents the cumulative effect of cash flow, starting from the research and development phases of the new product concept, through building inventories in the early stages of production, where the level of sales does not yet balance the cash flow, to the phase of sales levels that allow generating a profit. Therefore, the project team cannot make mistakes, especially in the initial phases of the pre-market product life cycle, because the negative cumulative financial effects of these mistakes will be revealed, which is why making good decisions regarding the selection of the right ideas and concepts, and new product designs, becomes fundamental. That is why this conceptual and methodological study proposes a rank-resource method of new product project evaluation to achieve optimal portfolio of new product projects management NPPM in terms of value in the pre-market life cycle phase.

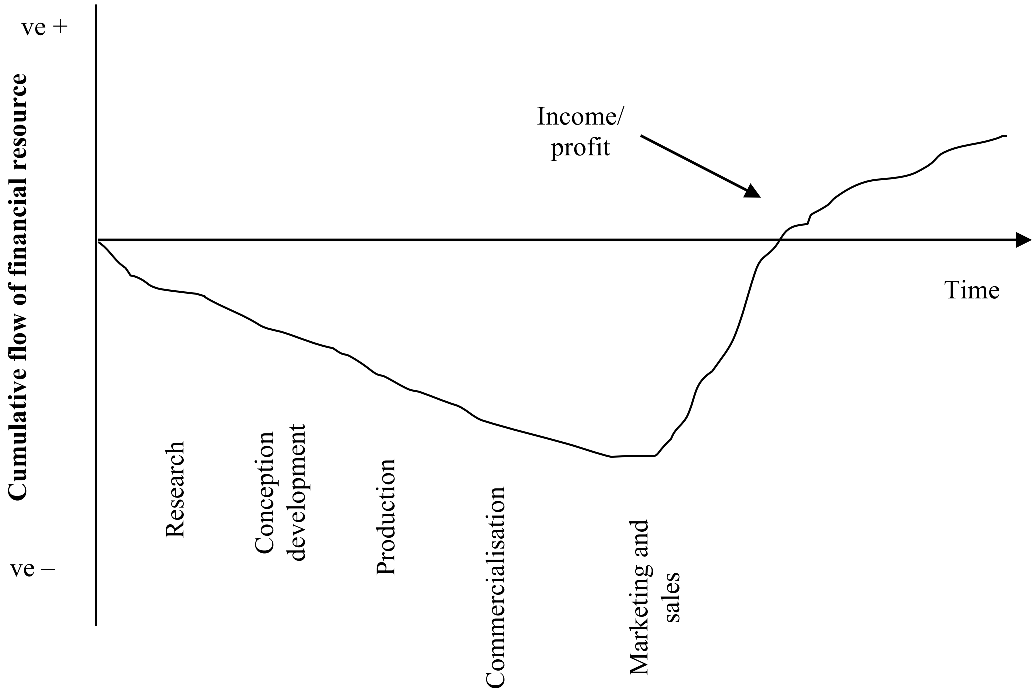

Figure 2. Cash flow and new product development
Source: own elaboration based on Trott, 2011

3. Problems, goals and factors related to portfolio analysis of new product projects

The success rate of new product development is significantly dependent on an enterprise's competences (Rutkowski, 2013):

1) in proper application of an integrated, concurrent new product development process (NPDP), its capabilities and maturity, taking into account the 'voice of the recipient,' based on a multidisciplinary team and other best practices (proper project execution – proper implementation of NPDP);
2) in proper selection of projects or design concepts for a new product (executing the right project).

Portfolio management in the area of new product development is a dynamic decision-making process according to which the project team constantly updates and revises the current set of new product designs. In this process, new projects are evaluated, selected, and their importance and priority are determined. Strategic decisions are also made about the allocation and reallocation of resources between active projects and whether to accelerate their implementation, change assigned priority or abandon (reject) the project. The portfolio management process is also characterised by uncertainty and changeability of information, dynamics of opportunities, diversity of goals and strategic conditions, interdependence between projects, as well as a variety of places and decision-making entities. It covers NPD decision-making processes taking place in the company, including a comprehensive review of all projects, formulating a new product development strategy and strategic allocation decisions (Cooper, Edgett, Kleinschmidt, 1999; 2000; 2001).

Portfolio management of a new product creates unique decision challenges for a modern enterprise, and the reasons for these unique problems are as follows (De Meyer, Loch, Pich, 2002; De Reyck et al., 2005; Kettunen at al., 2015):

1) portfolio management concerns future events, phenomena and opportunities, which results in information uncertainty and a lack of sufficient information base for project selection;
2) decision-making environment is highly dynamic, the status, perspective and scope of projects in the portfolio change as new information becomes available;
3) projects included in the portfolio are in various stages of implementation and compete with each other for required resources, hence the comparison of projects is made when there are different sets of information;
4) resources allocated between projects are limited, so the financing of a given project may result in the need to limit resources for others.

NPD best practice studies indicate certain reasons for an increase in importance of portfolio management which include: maximising the RF return factor, maximising R&D productivity, achieving financial goals, maintaining a competitive position by increasing sales and market share, proper and effective allocation of limited resources, creating links between the selection of projects and a new product strategy (the portfolio of new product concepts should reflect and support the strategy), focusing the design team on best concepts of new products, achieving a balanced portfolio of high and low risk projects in long term, consistent with the company's goals, better vertical and horizontal communication of priorities within the organisation, which increases the objectivity of project selection (Stabryła, 2015; Cabała, 2018).

Potentially, a conflict can arise between the above-mentioned macro goals of portfolio management. For example, maximising the value of the portfolio leads to the maximum net present value (max *NPV*) or internal rate of return (max *IRR*) of given projects, although such a situation may indicate an unbalanced portfolio of projects. Therefore, when choosing the methods of portfolio analysis, the hierarchy of goals for managing new product development should be taken into account.

Among the methods used to achieve the maximum value of portfolio of new product projects, financial models based on discounting methods have a significantly limited application. As they are based mainly on financial goals, they do not take into account strategic conditions and the probability of success and risk or assume accurate financial estimates.[2] These commonly

2 Although some companies try to assess the attractiveness of projects on the basis of *NPV* or *DCF* discounted cash flow, such calculations must be considered of little value, because uncertainty inherent in R&D is so important that rigors required by *NPV*, *IRR*, *ROI* methods make these calculations useless or even pointless.

known economic methods are mostly used for the evaluation and selection of investment projects (the purchase of a new technological line, machine, etc.). They are characterised by correctness and clarity of definition, and procedures for their practical application can be found in the sources cited above. The attractiveness of a project is determined by both qualitative and quantitative factors, while its value is determined by quantitative factors (Rybicki, 2000).

An important challenge from the point of view of project management is to encourage employees to create new ideas in the project path emerging in an organisation, as they are an important element of strategy renewal. Another issue that is particularly important in today's competitive conditions is the issue of portfolio management in the context of organising research and development activities, as well as innovative activities of the enterprise (Mikkola, 2001; Killen, Hunt, Kleinschmidt, 2008; Cooper, 2014). The literature emphasises also the role of project manager as a change leader, relationship moderator (gatekeeper), facilitator, trainer, and mentor. The involvement of senior management and its key role in the process of supporting launched initiatives is also discussed (Loch, 2000; Brzozowski, 2014).

In the traditional sense, a new product projects portfolio is a properly selected set of projects and their collections that compete for limited resources of the parent organisation. An appropriate selection of projects for the new product portfolio allows to properly balance the risk associated with its implementation (Hofman, Spalek, Grela, 2017). Attention is also paid to the strategic dimension, manifested in compliance of the portfolio's new product strategy and goals with strategic assumptions of the organisation (Meskendahl, 2010). In this case, defining the new product projects portfolio's goals consists in decomposing adopted strategic plans to the level of portfolio objectives. It is also necessary to define ways in which the performance of the portfolio will be monitored, and to analyse the availability of resources necessary for the portfolio to create desired results. Thus, a properly structured project portfolio allows for the implementation of the organisation's new product development strategy in whole or in part (Crawford, Di Benedetto, 2011; Nakata, Di Benedetto, 2012).

4. Methods of evaluating a new product projects portfolio

In a situation where the assessed projects require different amounts of resources (in terms of value and/or duration of capital expenditure), an individual *NPV* value cannot be used for their assessment and selection, as this value does not accurately express differences in the level of profitability of different project variants and resources required for their implementation. Therefore, the net present value rate (*NPVR*) should be used to compare different projects (Rutkowski, 2016). The basis for the evaluation and selection of projects is the maximisation of the *NPVR* indicator which is expressed by the formula:

$$NPVR = \frac{NPV}{PVI},$$

where:
NPV – net present value generated by a successful project (amount of benefits – discounted value of expenses and cash inflows),
PVI – present value of required capital outlays necessary to generate net income (discounted overall outlays – costs of the project).

Expenditures here are actual or potential expenses related to the implementation of a new product development process. Expenditures may differ from development costs in terms of time, subject scope and valuation basis. To achieve the maximum value of a new product projects portfolio, extended indicators can also be used, taking into account risk factors and subjective assessments of the technical and commercial value of a project which reduce the expected benefits. For this purpose, here is proposed the F. Olsen model of the economic value of the project and H.I. Ansoff's design quality factor (Olsen, 1955; Ansoff, 1964):

$$\text{Olsen model } V_p = \frac{r \times d \times m \times s \times p \times n}{PVI} = \text{economic value of a given project;}$$

$$\text{Ansoff model } Q_p = \frac{r \times d \times m \times (T + B) \times E}{PVI} = \text{design quality factor;}$$

where:
r, *d*, *m* – are respectively the success probabilities of the pre-design phases (research), concept design and development, and commercialisation (marketing),
s – estimated annual sales volume, *p* – profit per product unit, *n* – market life cycle of the product in years,
T, *B* – subjective assessment of the technical and marketing value of the project,
E – present value of expected revenue after successful product launch, i.e., *NPV*.

Thus, estimated numerical values in these models are adjusted by probabilities of conceptual, technical and marketing success of the new product. Another method of evaluating projects presented by G.L. Urban and J.R. Hauser allows us to determine the so-called attractiveness index for various projects in the portfolio, as the quotient of probability of expected return on investment related to the new product (research, development, commercialisation) and its development costs *Dk* (Urban, Hauser, 1990). This relationship is presented in the following formula modified by the author:

$$I = \frac{T \times C \times P}{\log D_k} = \frac{P_{si}}{\log D_k} \text{ attractiveness index of new product projects}$$

This indicator takes into account the P_{si} innovation success probability coefficient, which is the product of partial probabilities, i.e., the success of technical development (*T*), commercial development, provided that technical success is achieved (*C*), and economic benefits (*P*) resulting from commercial (marketing) success. High partial probabilities increase the feasibility and value of a new product concept at a given level of estimated expenditure on its development. The portfolio should include those project concepts that have achieved the highest values of the attractiveness index, higher than the arbitrarily adopted threshold index. Threshold indicators should also be defined for other methods used to maximise the value of the project portfolio. It can be assumed that the threshold indicator will be the average value of the calculated indicators for individual projects.

R.G. Cooper, S.J. Edgett and E.J. Kleinschmidt propose the expected commercial value method (*ECV*) for the evaluation and selection of designs or projects, as well as maximising the value of the portfolio, taking into account budgetary conditions and introducing the risk and probability concept. The *ECV* calculation is related to decision tree analysis (the NPDP phases are in the decision tree format) and takes into account the present value of expected *NPV*, the probability of commercial (marketing) and technical success along with overall development and commercialisation costs of the project (Cooper, Edgett, Kleinschmidt, 2000; 2001):

$$ECV = [(NPV \times Psm - Ck) \times Pst - Dk],$$

where:
Pst – probability of technical success,
Psm – probability of marketing success,
Dk – development costs (expenditures that must be incurred to complete the project),
Ck – commercialisation costs – future market launch costs.

To compare different designs of new products, the *ECVR* indicator expressed by the following formula should be used:

$$ECVR = \frac{ECV}{D_k} \text{expected commercial value rate.}$$

The sum of expenses that must be incurred to complete projects approved in accordance with rank may not exceed the limit of the previously planned total budget for the development of new products, i.e., $\sum_{x=1}^{n} D_k \leq$ the development budget. Expenditures previously spent on a given project, until it is completed and introduced into the market, are lost, and therefore should not be included in the calculation and ranking of the project commercial value as well as in making decisions: 'Accept-Activate,' 'Suspend,' 'Reject.' Some similarity to the *ECV* method is characterised by the productivity index (*PI*) of D. Matheson and M.M. Menke. This indicator allows us to maximise the financial value of a project portfolio given resource constraints. The formula of the new product design productivity index (*PI*) is as follows (Matheson, Menke, 1994):

$$PI = \frac{ECV_E \times P_{st}}{D_k}.$$

In this formula, the expected commercial value of *ECVE* is a different value than that presented in the indicator of expected commercial value of *ECV*. *ECVE* is an estimate of expected net discounted value (*NPV*). This probabilistic-statistical method used to assess the value of projects and their risk is related to the calculus of probability, the determination of expected values and statistical methods. The application of this method is much more difficult than the application of methods presented earlier. The basic tools of these methods are: normal distribution, indicators of occurrence of the probability of specific variables, as well as variance and standard deviation, Monte Carlo method, and others.

A single project will be profitable if the expected value of *ECVE* is greater than zero ($ECVE > 0$). The scale of associated risk is evidenced by the level of standard deviation of *SNPV* and coefficient of variation. It can be assumed that standard deviation and coefficient of variation are determinants of quasi-margin of project activation safety. It is important that the involvement of resources in a given project is aimed at minimising these factors. When two projects are compared, two cases may occur: a higher expected *NPV* is accompanied by a lower standard deviation ($ECVE_{(}x_{1)} > ECVE_{(}x_{2)}$ and $SNPV,x_1 > SNPV,x_2$). A project with a lower coefficient of volatility is then selected, as this project guarantees a higher compensation for the risk incurred. The coefficient of variation can also be used to estimate premium risk. The higher the ratio, the higher the risk of implementing a given project.

5. A modified rank-resource method of new product projects evaluation

The above-presented indicators generally seem to be simple and easy to apply, and the expression of benefits as only the financial criterion allows us to maximise the value of a new product projects portfolio focused on new product development process maturity in conditions of limited resources. The main weakness of these quantitative methods is their dependence on accurate quantitative financial data and probability estimates of an assessed project's success. In addition, these methods do not take into account the balance of a project portfolio, considered on the basis of risk level (except for the productivity index), market segments served, or the level of technology advancement.

At this point, another rank-resource method of valuing projects/programmes in the NPDP funnel (the portfolio of projects at individual stages of the development process) can be proposed, containing both qualitative and quantitative criteria. In this method, proposed by the author, specific factors, both quantitative and qualitative, make it possible to determine the level of attractiveness of projects and, at the same time, to analyse the strengths and weaknesses of a given project. On the other hand, only quantitative criteria concern specific resource constraints (limits) set by the project team: the time needed to complete the project *t*, personnel *K*, technical resources of *TR*, expected commercial value of the *ECV* project, and above all related to this indicator, future development and commercialisation costs and appropriate probabilities of the new product project's success.

The analysis and evaluation of criteria affecting the attractiveness of a project requires their prior identification, the adoption of a rating scale of 0–10[3] and proceeding according to the procedure used in the scoring method. Taking into account determinants of development and success of a new product examined so far, generally aggregates of project attractiveness factors can be presented as follows:

1) strategic fit – *SA* (compliance of the concept with the product strategy and the company's strategy, the degree of affinity with the company's existing marketing offer, the level of complementarity (deepening the product line) or substitutability (extending the product line), and the level of financial and material resources utilised (degree of their use);
2) advantage of a new product – *NPA* (product innovation, new physical and aesthetic features, new product properties, new technical features and usability characteristics, structural properties, including quality, potential price, product brand, type of material and raw material, additional benefits, potential unit costs variables, potential product profitability, and standards and legal requirements for product parameters);
3) attractiveness of the target market – *TMA* (market growth rate, market potential measured by turnover, potential of new and existing customers, location of customers and their bargaining power, potential of new and existing suppliers, location of suppliers and their bargaining power, intensity of competition and strength of competition, strength of seasonality and demand substitutability, and marketing service costs);
4) functional compliance with the company's key competencies – *CCA* (knowledge resources, qualifications and experience, the type of organisation, the level of internal competencies in functional areas of the company's operations, the level of forecasting and programming of the company's strategic activities, teamwork skills, the ability to assimilate new ideas, methods, as well as processes and products);
5) level of ability and technological maturity – *TCM* (originality and modernity of technical solutions, the scope of specialist knowledge and technical skills, the domain of basic research, the level of construction and design work, the use of laboratory tests and measurement techniques, Beta utility, and the type of original technologies);
6) level of potential benefits at a given level of risk – *RRL* (profitability of production/sales, risk level of research, development and marketing (technical, market));
7) level of the relationship network maturity – *RNM* (an intelligent network of relationships is a multidimensional cultural, business, technological and environmental space for functioning of the project team or new product development department responsible for managing the new product development process and the introduction of the new product into the market);
8) level of new product development process maturity – *NPDPM* (defines key practices that describe and differentiate successive levels of process maturity; the process phase includes groups of practices/activities the joint implementation of which leads to the achievement

3 Assuming that distances on the scale are the same, we assume that we are dealing with an interval scale according to the Stevens classification of scales (Stevens, 1946).

of specific goals; each process area consists of a specific number of goals the achievement of which guarantees the full implementation/execution of a specific phase of NPDP and making a decision of the type of activate-pause/hold-reject);

9) level of resource allocation – *RA* (the new product project should be evaluated for resource availability and allocation; the project team should have the necessary skills, experience, and resources to complete the project successfully);
10) level of alignment with regulatory requirements – *ARR* (the new product project should be evaluated for its alignment with regulatory requirements and compliance with legal, ethical, and social standards).

The use of this model allows us to create a strategically matched portfolio of new product projects that reflect the company's priorities in terms of resource disposal. And above all, it allows us to make right decisions, and thus avoid type 1I errors of rejecting good projects and type 2 errors of accepting bad ones. The result of good decisions will be an optimal portfolio of projects in terms of value. The model of finding a new product projects portfolio optimal in terms of value, using the rank-resource method, is presented in the Table 2.

Table 2. Modified rank-resource method for evaluating new product projects/designs

Project name	X_1	…	X_n
Strategic adjustment *SAdj*	$Sadjx_1 \in [0–10]$	…	$SadjXn \in [0–10]$
New product advantage *NPAdv*	$NPAdvx_1 \in [0–10]$	…	$NPAdvXn \in [0–10]$
Target market attractiveness *TMAtr*	$TMAtrx_1 \in [0–10]$	…	$TMAtrXn \in [0–10]$
Compliance with the company's core competencies *CCA*	$CCAx_1 \in [0–10]$	…	$CCAXn \in [0–10]$
Ability and technological maturity *TCM*	$TCMx_1 \in [0–10]$	…	$TCMXn \in [0–10]$
Potential benefits at a given level of risk *RRL*	$RRLx_1 \in [0–10]$	…	$RRLXn \in [0–10]$
Level of relationship network maturity – *RNM*	$RNMx_1 \in [0–10]$	…	$RNMXn \in [0–10]$
Level of new product development process maturity – *NPDPM*	$NPDPMx_1 \in [0–10]$	…	$NPDPMXn \in [0–10]$
Level of resource allocation – *RA*	$RAx_1 \in [0–10]$	…	$RAXn \in [0–10]$
Level of alignment with regulatory requirements – *ARR*	$ARRx_1 \in [0–10]$	…	$ARRXn \in [0–10]$
Assessment of project attractiveness (ranking database) *PAtr*	$PAtrx_1 = \sum$ factor ratings /100	…	$PAtrXn = \sum$ factor ratings/100
Time limit for project completion *t*	tx_1	…	tXn
Full-time staff *FTE*	$FTEx_1$	…	$FTEXn$
Cumulative number of Full Time Staff	$FTEx_1$	…	$FTEx_1 + FTEXn$

Project name	X_1	…	X_n
Expected commercial value rate of project *ECVR*	$ECVRx_1$	…	*ECVRXn*
Priority and Status (strategic decision type) Accept-Activate A-A, Pause – Hold P-H, Reject R	A-A, P-H, R	…	A-A, P-H, R

Specify: attractiveness threshold, e.g.: at a level of 0.75, employment threshold, e.g.: at a level of 45. ECVR threshold that activated project must meet, e.g.: 1.10. Then, the projects that meet the above-listed criteria should be ranked according to the attractiveness rating from max to min. Select those projects that do not exceed the resource limit.

Source: own elaboration

The above-presented method takes into account important decision variables, qualitative and quantitative, solves the problems of project implementation time, the attractiveness of the product, and sources of additional resources, as well as ways of their allocation at a given level of probable success of a given product concept which is part of the project portfolio. The relatively high complexity of this method cannot be its weakness, while its application contributes to increasing effectiveness of decisions made by the project team. In addition to creating the appropriate value of the project portfolio, another important goal is to maintain a balance of portfolio management in NPDP, i.e., achieving the desired balance of projects due to adopted dimensions of portfolio analysis (balance parameters). It can be assumed that basic determinants of project portfolio balance may be:

1) project maturity level, expressing the projects' ability to achieve the goals set for them in the new product development process and the project team's ability to implement and market them at a certain level of process maturity;
2) position of attractiveness and competitiveness of projects, indicating their ability to achieve market success;
3) potential level of cash flows (including other resources), development costs and cumulative potential benefits;
4) level of risk depends on the scale of originality and complexity of the project (development and technological risk) and the level of adaptation to the needs of recipients (marketing risk);
5) amount of time needed to complete the projects.

6. Conclusions

Over the last decade, the tendency to increase revenues from new product sales in companies has strengthened (new products have an increasing share in total sales, i.e., the sale of a new product on the market must generate a certain level of profit for the company in an increasingly short time (hence the tendency to shorten the market product life cycle). Therefore, it can be concluded that the company's future development opportunities are indeed conditioned by maintaining an optimal portfolio in the long term, rather than a mature one, as indicated in the literature (there is a weak correlation between profitability and market share). It can be assumed that balancing the product portfolio comes down to its optimisation, so important issues to be resolved in future studies are:

– what quantitative and/or qualitative dimensions should the project team adopt for the portfolio analysis in order to search for the balance of the project portfolio?
– is the portfolio of mature projects optimal and balanced at the same time?
– how to safely use artificial intelligence (AI) in the new product development process?

In practice, the project team may use various dimensions (balance parameters) on the basis of which the project portfolio will be plotted and the analysis will be conducted. Balance parameters are single or multi-property composite indexes based on quantitative and qualitative indicators presenting the value of product development project or programme for the project team (company). The use of both qualitative and quantitative balance parameters reduces the risk of making wrong decisions, in particular in early stages of the new product development process. In addition, the level of use of project portfolio analysis methods may have a specific impact on the level of a new product's market success.

Thus, there are many balance parameters, dimensions or variables that can be used when looking for a balance in the project portfolio. As a result, we get theoretically countless different maps showing the portfolio balance. In this situation, the key issue in balancing the project portfolio is the choice of time, determining the required amount of time for the implementation of a given project. The time of new product development determines the continuity of stream of new products introduced into the market. In addition to the time dimension, the type of project, or in other words the type of a new product being developed, and the directions of allocation of available resources related to this problem are also important.

Artificial intelligence (AI) for developing new products has applications in various business sectors. In the automotive industry, companies are considering using smart algorithms to produce cars faster, making cars eco-friendly and safer, while taking into account production costs and size. Artificial intelligence enables digital testing and prototyping of new products before the company spends time and resources physically creating the final form of the new product. AI can predict whether a given new product design will be unsafe, unsuitable, defective, or will not meet demand expectations. If company managers acquired enough quality data and applied artificial intelligence, these companies could see the future of their new products without producing or creating those products. Therefore, AI gives them a chance to adjust the new product development process appropriately at the concept, design or prototyping stage. New product development already relies heavily on AI, and companies that understand this can add more value in less time at less cost. This effect can be achieved by properly defining the new product strategy, selecting product concepts and designs characterised by a high probability of technical and marketing success, and by achieving a balance of the project portfolio in the long term.

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Metody wartościowania projektów nowego produktu w procesie zarządzania portfelowego w prerynkowych fazach cyklu życia produktu

Streszczenie: Celem artykułu jest przedstawienie metod wartościowania projektów nowego produktu w procesie rozwoju nowego produktu, a także zaproponowanie nowej metody optymalizacji wartości portfela projektów nowych produktów w prerynkowych fazach cyklu życia. Poziom powodzenia rozwoju nowych produktów jest istotnie uzależniony od stopnia kompetencji przedsiębiorstwa, po pierwsze w realizacji procesu rozwoju nowego produktu (PRNP), a po drugie we właściwej selekcji i wyborze koncepcji projektów nowego produktu (wykonywanie właściwego projektu). W szczególności z tym drugim obszarem kompetencyjnym związana jest problematyka zarządzania portfelowego w zakresie rozwoju nowego produktu. Mamy tu zatem do czynienia z dynamicznym procesem decyzyjnym, zgodnie z którym zespół projektowy ciągle uaktualnia i urealnia oraz rewiduje bieżący zbiór projektów nowych produktów. Podejmowane są także strategiczne decyzje o alokacji lub realokacji zasobów między aktywne projekty oraz o tym, czy należy przyspieszyć ich realizację, zmienić nadany priorytet, czy porzucić projekt. Jest to praca koncepcyjna i metodyczna, oparta na fundamentach zarządzania strategicznego. Dotyczy badań nad rozwojem nowych produktów. Ograniczenia metodologiczne i badawcze zidentyfikowane w tym artykule wynikają z ograniczeń czasowych, finansowych czy dostępności informacji. Rezultatem naukowym artykułu jest propozycja metody rangowo-zasobowej wartościowania projektów – programów w PRNP (portfolio projektów na poszczególnych etapach i bramkach procesu rozwoju), zawierającej zarówno kryteria jakościowe, jak i ilościowe.

Słowa kluczowe: zarządzanie nowymi produktami, metody portfelowe, zarządzanie portfelowe, nowe produkty, proces rozwoju nowego produktu

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