Corporate asset management – an integrated model for investment portfolio assessment

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Abstract: Assessing the value of investments can be considered a multidimensional problem and a continuous process wherein the decision-maker is confronted with multiple needs, requirements and values. Thus, all investments and investment portfolios should be evaluated, selected and prioritised not only in terms of money, but also with regard to dependability, sustainability and other aspects to be able to form the optimal investment portfolio. This paper proposes a life-cycle cost-oriented portfolio analysis model that will better serve investment decision-making in the capital-intensive industry. The conceptual model includes economic assessment, risk assessment, as well as strategic and technical analyses. From a long-term perspective, applying a more integrated approach to investment portfolio assessments generates several benefits, including advancing companies' and stakeholders' abilities to manage investments and to support the goal of sustainable business growth.

Keywords: asset management; portfolio management; investment; investment portfolio; life-cycle costing; life-cycle cost; life-cycle profit; financial assessment; investment appraisal; decision-making.

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1 Introduction

Sizeable investments in fixed assets are typically needed in capital-intensive industries to generate a reasonable sales volume and to satisfy specified economic, environmental, social and other requirements (Hastings, 2009). Therefore, the most important strategic decisions often deal with maximising the value generated by investments in fixed assets and aligning them with the strategy. It is important not only to support the success of a single investment, but also to maintain a portfolio of investments for the long run (Cooper et al., 2001).

An investment project portfolio can be considered as a collection of investment projects managed under a common budget to achieve aims (Killen and Hunt, 2013). The purpose of portfolio management is to select and prioritise the investment projects, whereas the purpose of multiple investment project management is merely to allocate the resources among the projects. Thus, portfolio management presents a complex set of challenges to decision makers also in the capital-intensive industry. Multiple projects must be configured and managed in a way to enhance the long-term strategic value of the portfolio while considering multiple criteria and interdependencies (Komonen et al., 2012; Martinsuo and Killen, 2014). Even though it is evident that selecting the right set of investments is critical for companies, portfolio management is typically very poorly handled in companies operating in capital-intensive industries (Heikkilä et al., 2012). Building future success through investment portfolios should be a significant part of corporate investment strategy.

Assessing the value of investment portfolios can be considered a multidimensional problem and a continuous process wherein the decision-maker is confronted with multiple needs, requirements and values. The significance of different business drivers (e.g., capacity maximisation, cost efficiency, quality improvement, sustainability perspective) at the time the decision is made affects the decision (Heikkilä et al., 2012). Thus, it is important to take into account that comprehensive and integrated asset management approaches require interdisciplinary know-how and competence. In particular, there is an evident need to combine methods used in engineering and economics (Komonen et al., 2012). Moreover, all investments and investment portfolios should be evaluated, selected and prioritised, and not only in terms of money, but also with regard to sustainability and other aspects, to be able to form the optimal investment portfolio. Therefore, it is evident that no single method or tool is capable of capturing all the viewpoints and concerns, and a variety of evaluation approaches and tools should be used (Cooper et al., 2001). However, this is not always the case in companies. As a result, investment decisions are often based on conventional investment appraisal tools and/or based on an inadequate evaluation not covering all the aspects.

In addition, there are some common challenges in developing multidimensional frameworks and tools to assess investment portfolios. Various authors advocate the need for the development of quantitative assessment frameworks and analytical models that can integrate multiple performance measures into investment portfolio assessment (Komonen et al., 2012; Martinsuo and Killen, 2014; Varsei et al., 2014). While there have been efforts assessing environmental sustainability, to date, there are still gaps in the current literature in terms of measuring social sustainability and how it can be integrated into assessment models as well as investments decision-making processes (Varsei et al., 2014). To sum up, decision-makers lack suitable tools to assist in the context of investment portfolio management. To address this concern, this paper presents a multidimensional investment portfolio assessment framework incorporating strategic, economic and technical performance and risk measures.

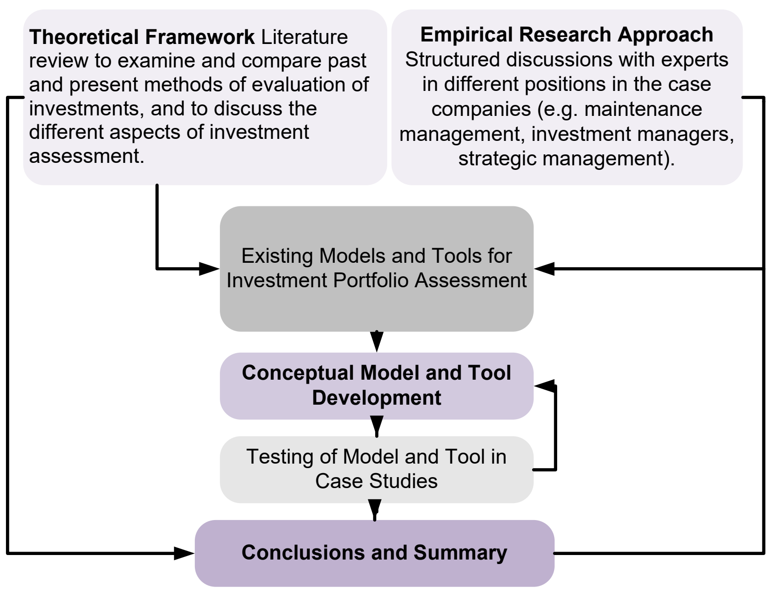
The rest of the paper is arranged as follows: Section 2 describes the research aim and design. Section 3 is dedicated to the methods for assessing investment portfolios. In Section 4, the developed integrated model for investment portfolio evaluation and its modules are introduced. In Sections 5 and 6, the main findings are discussed in a summarised form, and conclusions and recommendations for further work are drawn.

2 Research aim and design

This paper presents a life-cycle costing-oriented portfolio analysis model that will better serve the investment decision-making in the capital-intensive industry. The purpose of the paper is to contribute to the understanding of investment portfolio management in capital-intensive industry – i.e., how to ensure that the company or business unit level goals for the investment decisions can be reached. Furthermore, the model and the software prototype based on the developed model focus on fulfilling the gap between theoretical approaches and companies' needs for supporting investment portfolio decision-making in a fast-changing business environment. The underlying research question of the study is: how could a usable model for conducting an integrated appraisal be constructed?

In the research process of this paper, the focus has been on the concept development on the one hand, and on the empirical work on the other. In the conceptual part, the main aims have been to understand the multidimensional value of investments, to develop a conceptual model for the integrated evaluation of investment portfolios and to discuss the linkages between the economic evaluation and other analyses within the developed portfolio assessment model. The empirical work has verified and further developed the conceptual ideas concerning the multidimensional nature of the investments and the assessment concept that could support multifaceted decision-making in the best possible way (Figure 1).

Figure 1 Research process (see online version for colours)



The paper adopts a top-down approach where the requirements are derived from the business decision-makers' needs. The research question is tackled by applying constructive research as the research methodology. The conceptual research aims at the creation of new concepts or entire concept systems, or simply seeks to analyse and organise the existing ones to construct conceptual frameworks or systems (Labro and Tuomela, 2003). The research was conducted in close cooperation between the researchers and four large companies from different sectors of capital-intensive industries (i.e., forest, chemical and oil refining industries) in Finland. On the focus were asset investments in a company level, decision-makers in companies and interaction between individual decision-makers. During the research, the framework and the software prototype for evaluation of investment portfolios were developed, tested and validated. In this paper, the aim was to create in-depth understanding of the studied phenomenon and therefore the methodological choice was a single case study with multiple analytical units (cf. also Yin, 1994).

During our research, the material was gathered from a survey of research literature and from structured discussions with experts in different positions in the case companies (e.g., maintenance management, investment managers, and strategic management). The assistance of the case company employees was also used in software prototype development and testing.

3 Evaluating investment portfolios

There are plenty of established portfolio management tools and techniques to determine the value of proposed investments and to enhance the transparency of investment decisions. Early practices, mainly deployed before the 1980s, were often limited to the implementation of financial- and economic-oriented tools based on prevailing finance theory (e.g., Aas et al., 2016). Economic evaluation is usually conducted by means of quantitative measures such as net present value (NPV), internal rate of return (IRR), or payback period (Keeney and Raiffa, 1993; Dayananda et al., 2002; Pike and Neale, 2003). Additionally, a variety of life-cycle cost analysis methodologies for assessing the total cost of ownership of machinery and equipment, including its cost of acquisition, operation, maintenance, conversion and/or decommission exist (Cucchiella et al., 2014; Hanski et al., 2014). Lately, also multidimensional tools including additional performance dimensions have been developed and implemented (Aas et al., 2016). Examples of such tools include: bubble diagrams, product and technology road mapping, scoring models, decision trees, strategic buckets, analytical hierarchy process (AHP), Stacey's concept on the time horizon and uncertainty, risk and sensitivity analyses. In addition, current research suggests that the development of scenarios and the use of portfolio matrices, technology assessment and visual decision aids could support portfolio management decisions (Aas et al., 2016).

It is generally accepted that some investment portfolios in production assets are harder to appraise than some others because of their indirect future effects. Direct costs are most straightforwardly expressed in monetary terms. It is also relatively simple to find data on direct costs (Meyer and Upadhyayula, 2014). Therefore, the assessment of investment portfolios too often emphasises the evaluation of direct rather than indirect costs. Thus, the assessments are often under pressure to demonstrate short-term effects rather than emphasising the whole investment's life-cycle. However, especially investments in sub-systems for machinery and other production systems can and do have indirect impacts on profitability and sustainability. For example, the loss of opportunity through disruption of business is typically difficult to assess (Liyanage and Badurdeen, 2009). Life cycle costing standard also emphasises the consequential costs which may include warranty cost, liability cost, cost due to loss of revenue and costs for providing an alternative service (IEC 60300-3-3, 2017). Consequently, there is a lack of approaches to address the importance of indirect effects of investment portfolios. Furthermore, production assets in the capital-intensive industry have long life-cycles and during the operating time numerous rebuilds, replacements and expansion investments take place the effects of which are both direct and indirect and have a strong effect on sustainability.

Most company structures and business environments are complex and turbulent. Therefore, also investment decisions involve a considerable amount of uncertainty. For example, an investment in rationalisation or modernisation of production assets might take an unexpectedly long time to impact efficiency and, consequently, profit. Although there are specific methods for incorporating uncertainty into investment decision-making, it is, however, a very challenging task (Petit, 2012; Götze et al., 2015). In general, the term 'uncertainty' as used in strategic management and organisation theory refers to the unpredictability of environmental or organisational variables that impact corporate performance or the inadequacy of information about these variables (Miller, 1992). As the term 'risk' can be defined as combination of the frequency, or probability, of occurrence and the consequence of a specified hazardous event (IEC, 2009). Uncertainties, namely data, parameter and model uncertainty, can enter the investment decision-making process at different points, and these all affect the usefulness of the results. Furthermore, this paper argues that approaches that help to reduce uncertainty or assist in analysing its causes and effects are often too theoretical and complicated to be used in companies.

In general, novel integrated approaches for portfolio management is required to understand the impact of fast-changing business environments (uncertainty and turbulence), to develop integrated and dynamic planning and decision-making methods, and to use advanced multivariate methods and simulation models. There is also a need to enhance data collection and carry out more empirical studies (Komonen et al., 2012). Asset management also requires the integration of management science, industrial economics, operation research, reliability engineering and research of physical phenomena. In addition, the decision-makers should also take into account aspects that have not been formally addressed by the methodology but could affect the choice. In all, the actual decision should be based on the several decision criteria.

In the following section, the conceptual model and different analyses incorporated in the integrated model developed in the research project are discussed.

4 An integrated model for investment portfolio evaluation

4.1 Conceptual model for assessing the value of an investment portfolio

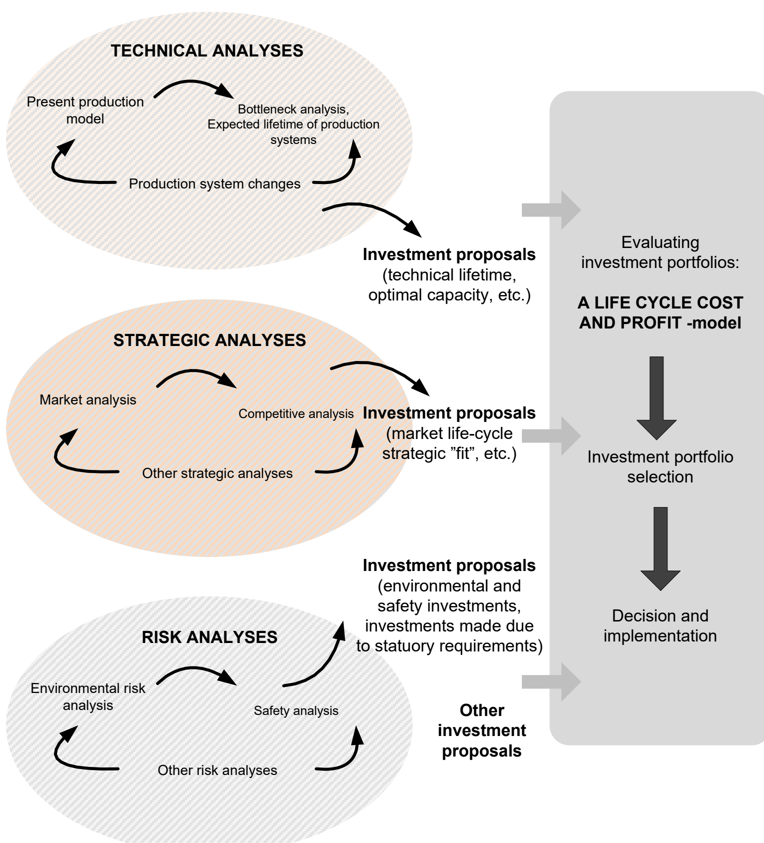
The project's case companies have faced some common challenges in evaluating, and managing investment proposals locally and globally across different plants and business areas due to a large number of investment proposals. The usage of plant-specific data format in investment appraisal, both for input data and for result indicators has complicated the comparison of investment proposals of various plants. There have also been challenges in comparison of different types of investments (e.g., investments in productivity, replacement and maintenance and for capacity expansion, investments made due to regulatory requirements). This situation has created a need for harmonising investment evaluation and for using and integrating information from different data sources and perspectives (technical, operational and strategic). The case companies' specific needs regarding the investment assessment were:

- Each investment should not be evaluated individually but rather the viewpoint of investment portfolio should be considered.

- Strategic viewpoint as well as technical, risk and economic aspects should be taken into account in the investment portfolio evaluation.
- Investments due to statutory requirements need to be carefully assessed for ensuring that they really need to be prioritised before other investments.

Keeping these main needs in mind, a conceptual portfolio evaluation model indicating the main inputs, outputs and linkages between different analyses was developed (Figure 2). The conceptual model indicates that the assessment should be integrated and thus include economic assessment, risk assessment, as well as strategic and technical analyses.

Figure 2 Conceptual model for assessing the value of investment portfolio (see online version for colours)

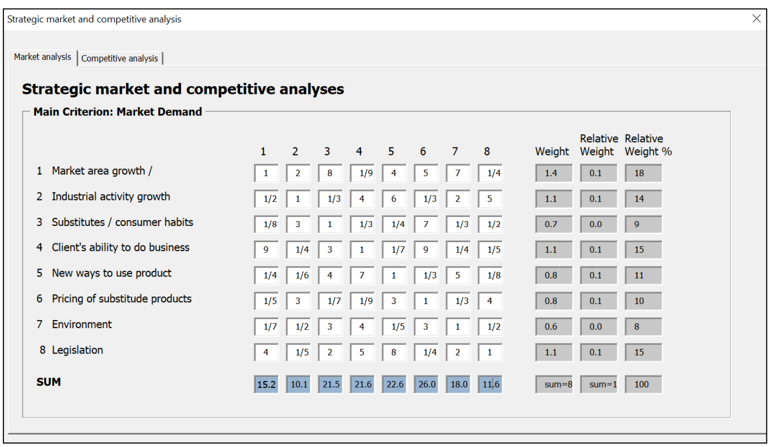


The starting point of applying the portfolio assessment methodology is a perceived need for investments in productivity, replacement and maintenance and for capacity expansion aimed at developing the company's current investment portfolio as well as narrowing current and future gaps related to strategic, financial and risk objectives. Additionally, decision-making can be considered a multidimensional problem wherein any purely economic, strategic, or risk-related assessment can be deemed inadequate for consideration of all relevant elements. Next, the various modules of the model are discussed in a more detail.

4.1.1 Strategic analyses

The aim of the strategic market and competitive analyses within the integrated model is to summarise the evaluation of the market demand trend and the competition position of the company, as well as to specify the additional capacity that can possibly be sold on the market. Thus, the market and competitive analyses link a corporation's strategic objectives into the investment appraisal. Both market and competitive analyses are semi-quantitative by nature and inspired by the methods and theories of strategic alignment, AHP (Saaty, 1980), expert judgment (IEC, 2009; Baybutt, 2018) and Stacey's (1990) concept related to the time horizon and uncertainty (see for example, Market demand, Figure 3).

Figure 3 An example of the graphical user interface in the software prototype developed in the project: pairwise comparison of the pre-defined factors under main criteria market demand (see online version for colours)



As a result, the method suggests the length of an economic life-cycle to be applied in the economic evaluation in the integrated model. Thus, the life-cycles of the different business and geographical areas are taken into consideration in investment calculations. The economic lifetimes to be used in the evaluation matrix (Figure 4) are based on the results of the market and competitive analyses. Furthermore, the maximum length of the lifetime is dependent on the investment type (e.g., machine or infrastructure investment). If both the trend of market demand and the competitive position of the company are strong, the lifetime which is suggested by the method to be used in the investment evaluation is ten years. Thus, the life cycles of the different business and geographical areas are taken into consideration in investment calculations. The semi-quantitative evaluation of the market and competitive environment integrates the corporation's strategic objectives into the investment appraisal method.

Figure 4 Impacts of market demand and competitive position on the economic lifetime to be applied in the economic evaluation of investments

Economic lifetime to be used in financial investment evaluation (years)

Market Demand							
Strong	6	6	10	10	10	10	10
	6	6	6	10	10	10	10
	3	6	6	6	10	10	10
	3	3	6	6	6	10	10
	3	3	3	6	6	6	10
	3	3	3	3	6	6	6
Weak	3	3	3	3	3	6	6

Weak Strong

Competitive position of the company

Source: Kortelainen et al. (2015)

In many cases, the investment life-cycle is still not a very clear and exact concept. There are different alternatives to determine the time horizons. Infinite planning horizons or the average lifetimes of machines can be used, i.e., calculations can be made for a certain planning period. Often, the going-concern principle offers a central argument for infinite horizons. However, this is not the whole truth. For example, when the development of markets is predictable, it is sensible to use long planning horizons, but when the movements of markets are highly uncertain and difficult to forecast, shorter horizons offer more flexibility for the future operations of firms (Kärri, 2007). In addition, there are also very long life-cycles, such as in the production systems of capital-intensive industries. Our research indicates that companies are typically using default lifetimes in calculations for production assets (e.g., 10 years) and for infrastructure investments (e.g., 20 years). However, this can sometimes be misleading and even give unreliable results, as the lifetime applied in investment calculations can have a significant impact on the profitability of the investment and investment portfolio. However, the economic fact is that the profits of an investment have to be earned during its economic life-cycle (Suomala, 2004). This is also why it is important to pay special attention to the determination of the length of a life-cycle used in calculations, and more cooperation is needed in companies between technical and financial experts than at present.

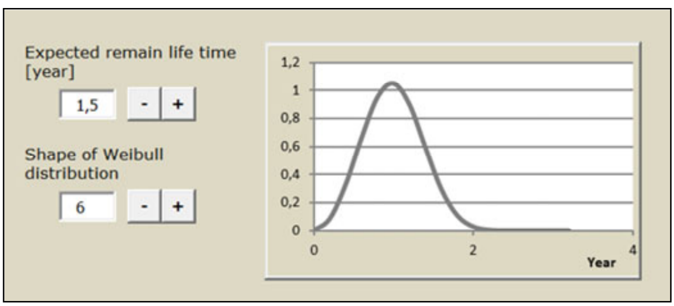
4.1.2 Technical analysis

Especially in the case of replacement and expansion investments, the importance of managing dynamics of cash flows is emphasised. A crucial task is to determine lifetime and optimal timing of investments. Successful timing has effects on the profitability of investments and investment portfolios. In our model, special attention is paid to the determination of the remaining lifetime and the consequential cost (lost revenue) of the production assets to be replaced. It is possible to forecast how different timing alternatives affect the profitability of an investment compared to the decision to continue the operation with the current asset can be forecasted. In fact, the consequential cost (e.g., lost revenue) for the current asset can be considered as a saving generated by the new investment. This indirect cost saving can be even higher than the profit generated by the decreased material consumption, decreased operation and maintenance costs, increased availability or better energy efficiency of the investment (see also Muchiri and Pintelon, 2008). The cash flow statement and the distribution of the consequential costs for the production asset to be replaced are formulated by the factors presented in Table 1.

Table 1 Timing and cost factors for technical evaluation

Timing	*Costs*
• Determination of the expected lifetime of the machine to be replaced • Determination of the form of the probability distribution for the breakdown time of the machine to be replaced	• Determination of direct and indirect costs if the old machine fails before the replacement investment is carried out • Determination of the form of the probability distribution for the costs • Determination of the discount rate to be used in cash flow statement

Figure 5 Software prototype: graphical interface for definition of expected economic lifetime for an investment (see online version for colours)



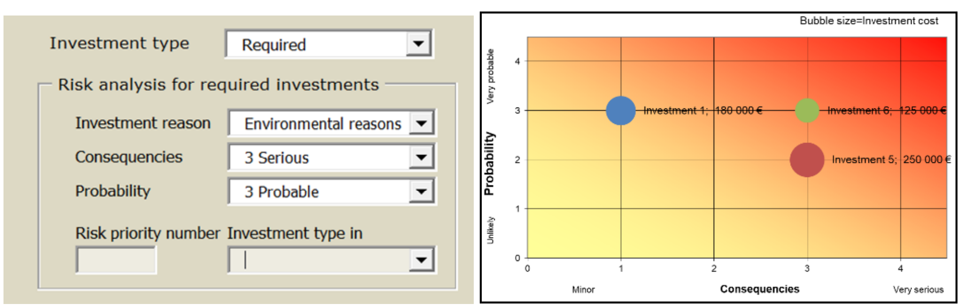
The timing aspect of investments is taken into account in the integrated model by using the Weibull analysis. It is appropriate for the lifetime evaluation as the form of distribution is very flexible and it generates positive values. First, the expected lifetime and the form of the distribution for the asset to be replaced are determined. On the basis of the Weibull distribution, which typically is used for describing the length of lifetimes (Si et al., 2011), the probability of the breakdown for each year of lifetime can be calculated. After the lifetime prediction, the costs occurring if the asset fails before the investment is realised, are estimated. Both indirect and direct costs should be taken into account, i.e., failure costs as well as unavailability costs. These costs are then allocated to the cash flow statement and divided to a yearly cash flow using the probability distribution of the remaining lifetime and linked to the economic evaluation. The discount rate to be used in cash flows is the same as in the economic evaluation (Räikkönen et al., 2016). The software prototype comprises also a graphical interface (Figure 5) which makes the definition of a distribution parameter possible even if a user is not familiar with statistical distributions. The user can change distribution parameter and immediately see the shape of a corresponding probability density function.

4.1.3 Risk analysis

During our research, a semi-qualitative risk analysis model was developed for environmental and safety investments, and for other investments made due to the statutory requirements. The risk analysis method was incorporated into the integrated model. This analysis, on one hand, aims at ensuring that the most attractive investments from the environmental and social sustainability point of view get appropriate focus, and on the other hand, that the investments due to environmental, safety and legislative reasons do not dominate within the limits of the proposed budget for investments in production assets.

In our model, the risk is defined in a common manner as the combination of probability (frequency) and the consequences of a certain scenario. Risk categories are defined according to consequence and probability ranges (measured on a scale of 1–4), and are presented in a matrix form. The risks are then assessed against the acceptability criteria. All investments that exceed the acceptability limit defined together with the researchers and the company representatives (probability * consequences > score 12) are automatically taken into the portfolio regardless of whether they are profitable in financial terms, or not. If the investment does not meet the acceptability criteria specified in risk analysis, the investment does not receive any special attention and is treated like any other investments to be evaluated and when the investment portfolios are generated (Räikkönen et al., 2010). The software prototype comprises also a graphical interface (Figure 6) for making a risk analysis for investments made due to the statutory requirements.

Figure 6 Software prototype: graphical interface and graph for analysis of risk of investments made due to the statutory requirements (see online version for colours)



Risk analysis depends heavily on human decision making in the form of engineering judgment and expert opinion. A variety of human and psychological factors may influence the risk analysis outcome. Such factors include, e.g., memory bias and motivation bias, and heuristics (Baybutt, 2018).Thus, the coverage of the expert group, competence of the experts and their commitment to the consequences of their decisions are of prime importance.

4.1.4 Economic evaluation

The economic evaluation process of the model consists of several steps. First, it is necessary to define the relevant cost and profit categories, which supports the estimation of the total costs and benefits of an investment, or a certain subset of an investment's life-cycle costs and profits. The developed model aspires to systematically embrace all present and future costs and profits of investments and, consequently, investment portfolios. All direct and indirect profits and costs, irrespective of whether they can be quantified and valued, should be identified. However, typically the 80/20 rule (i.e., Pareto's principle) can be applied: 80% of costs arise from 20% of cost categories and 80% of benefits arise from 20% of benefit categories. The assessment approach comprises of general, pre-defined cost and profit types, which are presented in Table 2 (see also Rødseth et al., 2016; Wudhikarn, 2016).

Table 2 Main cost and profit categories of the developed model

Cost savings/costs
Decreased/increased production time (incl. breakdowns, unplanned and planned shutdowns)
Decreased/increased material usage
Decreased/increased energy usage
Costs/cost savings if the current production asset fails before the investment is carried out
Decreased/increased reject
Increased/decreased maintenance costs (other)
Increased/decreased operating costs (other)
Profits
Increased capacity and additional sales that can be sold at the market
Capital costs
Investment costs

There are a number of alternative methods for valuing the costs and profits of investment portfolios, the methods are suitable for different purposes and they vary in how accurately they present the value of impacts. Often, for example, engineering and manufacturing estimates for costs and related profits are available (market prices). Older estimates may be updated to the present time with appropriate factors, such as annual discounting and escalation factors. In addition, it should be taken into account that comparing cash flows from different periods can be achieved only by incorporating the time value of money (discounting). The chosen method should always reflect the decision situation at hand, the possibility to assign monetary values for different costs and profits and data availability.

Evaluation means literally determining the value or worth of an investment being considered in a specific decision situation. In our model, economic evaluation follows standard practices typically used in industrial companies. It also uses the results of the other analysis modules (strategic, technical and risk analyses) as discussed in Subsections 4.1.1, 4.1.2 and 4.1.3. As result of the life-cycle cost and profit evaluation, different types of economic indicators, as well as graphs, are calculated and presented for the investment portfolios. Typically many different result indicators are used as they can calculated based on the same data. In our model, the traditional financial indicators, IRR and payback time, are calculated for each investment. NPV is referred to in the model as discounted life-cycle profits (discounted LCP), as it takes into account specified performance, capacity, safety, reliability, maintainability and environmental requirements during the entire life-cycle of an investment. Figure 7 shows a screenshot from the software prototype presenting the example of the result indicators and portfolio content.

Figure 7 Software prototype: graphical interface and graph for portfolios and some key economic indicators (see online version for colours)

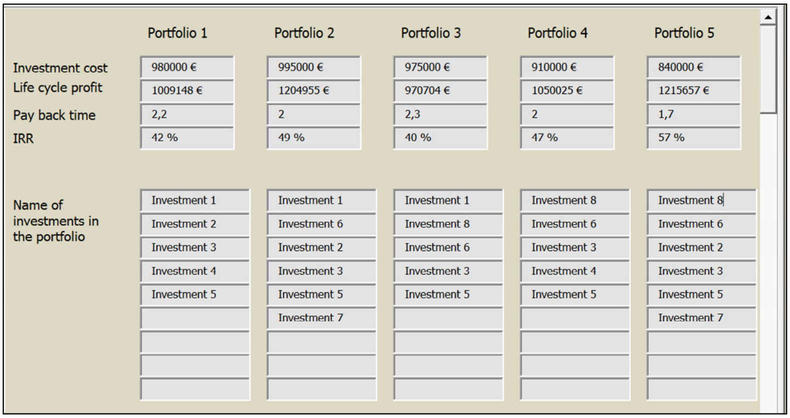
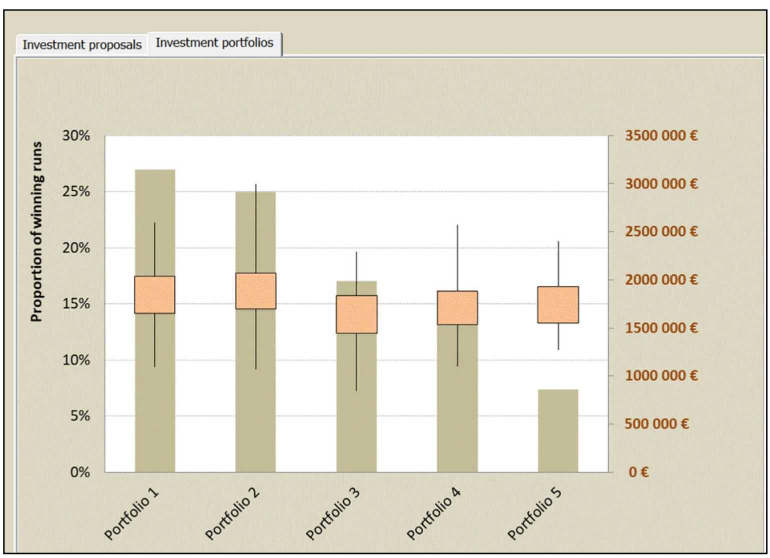


Figure 8 Software prototype: example of a result graph presenting distribution of expected life cycle profit of optional investment portfolios (see online version for colours)



Life-cycle costs and profit calculations are based on estimated future costs and profits, which inherently are uncertain. In the developed approach, the uncertainty is taken into account by a what-if analysis, which is conducted by a Monte Carlo simulation. The Monte Carlo simulation enables easy variation of several cost/profit factors at the same time and to repeat the analysis several times. The first investment portfolio is composed of investments for which original technical and economic input values are given. The constraint of the resource allocation is the investment budget and the decision-making criterion is the life-cycle margin. After the what-if analysis is repeated a couple thousand times, the most profitable investment portfolios and range of a selected result indicators can be determined. Statistical distributions required for Monte Carlo simulation are in this case defined by two parameters: one for distribution location and one for variability of distribution. These parameters are defined based on expert judgments. Location parameter is an estimate of expected cost/benefit value, e.g., expected annual maintenance cost or production volume if a current investment proposal would have been executed. The variability parameter is a user-defined proportion of expected value. High variability indicates high uncertainty related to current cost/benefit value.

The graph (Figure 8) presents the number of alternative investment portfolios formed in different simulation runs and proportion of simulation runs where each of those portfolios has been the most profitable.

Finally, a portfolio of investments that most optimally satisfies given economic, environmental and social objectives and strategic drivers is selected. After an investment decision is made, continuous evaluation is needed in order to maintain optimal portfolio performance.

5 Main findings

The integrated investment portfolio evaluation model presented in Section 4 provides a holistic view to investment decision-making by combining and integrating several evaluation methods into aggregated analysis and results. The approach consists of a combination of semi-quantitative and quantitative evaluation methods by integrating technical, operational and strategic information. The numerical and graphical results of assessment support the decision-maker in selecting the most optimal investment portfolio that is constructed under the economic and other constraints and offers the best return on capital.

The economic evaluation of investments is expanded by assessing investment portfolios instead of individual investments and by integrating results of semi-quantitative analyses into evaluation. By using Monte Carlo simulation, uncertainty related to future costs and profits of investments are considered, and alternative investment portfolios formulated. However, it needs to be accepted that the level of available cost and profit related data varies case by case, and economic evaluation part of the model has to allow calculations based on detailed data as well as coarser calculations with imprecise data.

Concerning semi-quantitative, i.e., strategic analysis section of the approach, expert judgment makes an integral part of it. Therefore the effectiveness of the approach relies partly on the decision-makers abilities to provide sound judgments. Subjective estimations are given for weights and impacts because they cannot be supported by empirical analysis. However, as with any decision calculation model, we must be aware of the limitations of subjective estimates. By performing a sensitivity analysis, the impact of changes in different calculation parameters can be analysed. In that way, uncertainty can be taken into account also in the context of semi-quantitative analysis provided by the approach.

The software prototype based on the developed approach is already being successfully applied in formulating and evaluating investment portfolios in the companies in capital-intensive industry that participated in the project. In practice, the integrated assessment resolves the challenges in the case companies' investment portfolio management. The model improves the quality of decisions, because the portfolios are comparable and effectively formulated. At the same time, the model supports communication and vision sharing between the organisational levels.

5.1 Limitations of the research and areas for further investigation

The developed conceptual model for investment portfolio assessment has its limitations as any empiric model. The concept and methodology were developed in close collaboration with the representatives in a capital-intensive company, and the feedback from the expert groups was collected on a regular basis. As an example of the response to the feedback, risk analysis was included to the integrated model in order to assure the justified prioritisation of the investments. Only the investments, that exceed the defined acceptance limit, are included in all investment portfolios regardless of their profitability.

One problem in managing investment project portfolio is the interdependency between investment proposals. In our project, the target was to develop an investment assessment approach and tools for practitioners and the proposed integrated model do not capture interdependencies in an analytic way. The model was tested with a set of modernisation and replacement investments that were collected from different departments of the plants. Due to the variety of individual investment proposals, the expert group did not address interdependency as a problem. However, further research is needed to create a method that allows the identification and screening of the interdependency of the investment proposals.

The integrated investment portfolio evaluation model and the methodological tools will be developed further, and they will be applied in different industry branches, and to different types of investments. The ongoing research on the customisation and use of integrated model in different contexts include investments in digital solutions and in autonomous systems. Further research is also planned on the use of environmental and social measures in the context of investment portfolios; and analysis of their potential linkages with economic value.

6 Conclusions

This paper highlights the importance of integrated assessment of investment portfolios and presents a conceptual model for integrating economic evaluation, technical analysis and risk analysis. Obviously, a single standardised method is insufficient for an overall investment assessment, and the actual investment decision should be based on several decision criteria. In practice, decision-makers should also understand the key assumptions behind combined assessments, how the assessments are executed, and what the final results really mean. The nature of the appraisal also depends on the available time, financial resources and information, and the viewpoint (company, customers, and society) from which the assessment is made. It is essential that the applied assessment methods are aligned with the quality and amount of available data. Moreover, the required depth of the assessment is dependent on the actual investment decision situation. Due to the multidisciplinary nature of the assessment, the various results must be interpreted together before the final synthesis or recommendations are offered.

Recently, the trend towards sustainable development and sustainable business growth has resulted in a growing interest in integrated impact and risk assessment. The need for integrating social and environmental aspects into the investment assessment is increasing and sustainability is becoming a dominant way of thinking, also in asset management. As environmental and social effects may constitute a significant part of the overall benefits (profit), they should be considered and integrated in assessments and decisions on production asset investments. However, these effects are difficult to measure solely in economic terms and further research is needed also in this field.

From a long-term perspective, applying a more integrated approach to investment portfolio assessments generates several benefits, including advancing companies' and stakeholders' abilities to manage investments and to support the goal of sustainable business growth. In the future, there will be greater need for more integrated investment assessment and for combining economic, social and environmental impact assessment procedures to support multi-objective investment decision-making. However, such a combined assessment is still in its infancy, and more development work is needed to relate different assessment methods to one another.

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