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More certainty in uncertainty: a special life-cycle approach for management decisions in volatile markets

Marcel Röser¹ 

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Abstract

Risk managers as corporate stewards are important gatekeepers in enterprises and they are essential to managing risks. Relatedly, a more accurate evaluation of the risk factors allows a well-founded decision-making process and reduces the number of surprising situations that could occur especially in volatile markets. Forward-looking risk management increases entrepreneurial resilience because risk factors are already estimated at an earlier stage in the corresponding risk analysis. Furthermore, the range of potential solutions can be estimated in a successive way. These aspects are relevant especially for products with follow-up effects. Such new product bundles are typical in current businesses. They require a more precise risk analysis, which allows an effective view of the life-cycles of the whole products and the customer relationships. Within well-founded risk decomposition, the existing risk can be managed appropriately. The following study presents a special life-cycle approach for evaluating products and customers in risky situations. Especially for important management decisions, such an approach is necessary, given that only a few products or customers can have a major influence on the success of the enterprise. Therefore, a systematic risk-oriented approach is essential that adequately identifies, assesses and controls the risk factors and enables agile adaptability for fast changes. Considering the risk management perspective, simulation techniques are a useful approach to solve sophisticated decision situations. The applicability of this concept is demonstrated using a computation example reflecting real-world circumstances. The presented approach is broadly defined. That is the reason why the approach can also be transferred to other sectors.

Keywords Risk management · Risk factors · Uncertainty · Resilience · Life-cycle analysis · Decision-making · Volatile markets

JEL classification D81 · M11 · M40 · M41

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1 Introduction to the importance of risk-oriented information for decision-making processes in volatile markets

Risk management is a main task for many enterprises. Digitalization, climate change, new product bundles and market disruptions are only a few examples of an increasing interest in risk management, especially in volatile markets. In the meantime, *risk management* is a major research stream in management accounting (Arena et al., 2010; Bailey, 2022; Hall et al., 2015; Huber & Scheytt, 2013; Jordan et al., 2013; Kaplan & Mikes, 2016; Mikes, 2011) because *forward-looking risk management* makes organizations more resilient when facing excessive risk-taking (Maffei & Spanó, 2021). In this situation, risk factors should already be estimated in a structured way at an earlier stage in the corresponding risk analysis. Therefore, many companies still improve their *management approaches* to handle risks proactively and through strategically oriented risk governance (Alexander, 2020; Grammenidis & Hiebl, 2021; Maffei & Spanó, 2021). In this context, a life cycle approach could help to establish a long-term risk assessment for a lot of management decisions. In line with internal turns in decision-facilitating and decision-influencing roles, more regulated *risk reporting* is needed, for example, by regulatory authorities and the government (Bhimani, 2020). This aspect is an upcoming task, especially in *financial accounting*. For internal decision-making processes, external-oriented reports are only helpful to a limited extent.

For *internal management processes* it is important to present the decision situation in an appropriate way. If we carry out well-founded risk analyses, a company can react more swiftly in the event of changes. In this case the risk report is the result of internal considerations and prognosis. It is not an outcome of laws and regulations. Therefore, *risk forecasts* may look different for internal decision-making purposes than for external ones.

This article deals in the following sections only with *internal* governance approaches. A useful internal risk governance approach not only promises improved risk response capabilities but also may help instill new thinking and forward-looking enterprises to tackle risks in a suitable manner (Sheedy, 2021). Relatedly, a more accurate evaluation of the risk factors allows a well-founded *decision-making process* and reduces the number of surprising situations that could occur. Forward-looking risk management also improves the decision-making process of the enterprise because risk factors are estimated and observed at an early stage of the decision-making process. In addition, volatile markets require a more detailed and adaptable risk analysis. To solve long-term decision problems, a year-specific life-cycle analysis can capture the risky parameters and we can estimate the bandwidth of each parameter and the overall performance over the lifetime.

To be able to implement such a differentiated approach on a conceptual framework, the theory of *marginal cost* is useful. The theory is well known in German-speaking countries as *Grenzplankostenrechnung* (Kilger, 1961; Plaut 1953) and was originally presented in the US literature by Harris (1936). To provide a theoretical basis for the methodology, I distinguish *four principles* of management

accounting in this paper (Troßmann & Baumeister, 2015; Ewert & Wagenhofer, 2006; Riebel 1994; Kilger 1961): Principle of Disponibility (PoD), Principle of Relevance (PoR), Principle of Marginality (PoM) and Principle of Situative Evaluations (PoE). I describe these principles as a theoretical foundation for this paper in Sect. 2.1.

Following the four principles of management accounting, a well-founded risk decomposition in an early stage leads to an anticipative risk control system in later stages. Product- and customer-related risk factors can fundamentally change management decisions and subsequent control processes. All aspects suggest a year-specific life-cycle approach because such an approach adequately identifies, assesses and controls all relevant risk factors over time. The approach can detect deviations at an early stage of the project. This can be an important success factor and an enabler for agile management in risky situations.

Resilience is one important factor in the evaluation process. It is the ability to respond, adapt and, if necessary, to restart in the wake of adversity (Korber & McNaughton, 2017; d'Andria et al., 2018). This includes a personal factor. It is understood to possess a stable personality trait reflecting flexibility to adapt to emotional events (Genet & Siemer, 2011). In this way, a resilient subject is robust, resourceful, perseverant, with high motivation and optimism (Fisher et al., 2016). However, beyond being considered a personality trait, resilience can also be interpreted as a *dynamic process* to deal with uncertainty (Sutcliffe & Vogus, 2003). Therefore, resilience can be a (learned) behavior process to respond in different situations in a better way.

Against this background a well-founded *Controllershship* is helpful, especially in uncertain situations. In general, risk-oriented controllership is a management function for coordinating interdependent problems in a goal-oriented and, above all, *risk-adjusted way*. This includes system-creating and system-filling tasks (Ewert & Wagenhofer, 2006; Horváth et al., 2020; Küpper et al., 2013). System-creating tasks mean, for example, the development of a risk-oriented behavioral management instrument. Such an instrument tries to align the behavior of the decision-maker to the company's goals (e.g., Rowe, 2004). In contrast, system-filling tasks occur regularly in daily business, for example, defining management-by-exception limits.

For a well-founded risk management approach, both steps are necessary. First, we need a conceptual way, e.g. an risk steering approach. After this baseline definition, we also need a controllership for continuous improvements in daily business. The different tasks determine the refinements in subsequent steps. In addition, this task addresses the service functions of controllership, e.g., the information function, the provision of methods, the decision-making support and the initiative function if mismanagement occurs.

Parallel to the changing framework conditions, enterprises regularly offered more *complex product combinations* in a competitive environment. The design of innovative *product bundles* is a challenge for many enterprises. One common goal of new products is to offer a complete customer-oriented package with integrated services over the customer relationship. Additional service packages are often included by the enterprise as an inherent part of new product combinations. Innovative product bundling has an impact on the market-oriented functions but also on the company's

internal risk-oriented processes, especially for management decisions. Therefore, such product bundles require an adjusted risk consideration in management decisions. To be able to solve internal management problems in a risk-oriented manner, the case-specific characteristics of such new composite products should be correctly considered.

Summarizing the initial situation, a special methodical approach is needed. For this purpose, a life-cycle analysis is a useful framework to solve methodological tasks. At this point, a research gap is apparent, because either a year-specific calculation is recommended in management accounting or an isolated risk analysis. The standard life-cycle concept does not consider risk factors in detail (Horngren et al., 2022; Pfeifer & Ovchinnikov, 2011; Sunder et al., 2016; Troßmann, 2018). However, both fields can be combined in an integrative way to create additional value for enterprises. In this context, a whole set of methodical questions with a broad range of applications and high *relevance* opens the view of a well-founded risk management analysis, especially from a managerial accounting perspective:

- How can a risk-oriented life-cycle approach be structured to adequately support management decisions in volatile markets?
- How can sector-specific factors integrate into the methodological approach?
- What recommendations can be derived from the risk-oriented calculation for management decisions?
- Can we improve entrepreneurial resilience with such risk-oriented life-cycle approaches?

This paper addresses these questions by means of the following steps. First, the methods are specified to represent the characteristics of each sector for internal management decisions without disregarding the principles. Such analysis requires, more than other calculation problems, *adequate* risk consideration to evaluate decision proposals. For solving such tasks, a few steps are necessary, e.g., the integration of a year-specific consideration and a simulative calculation of the relevant risk profiles. This approach can incorporate knowledge from several experts via typical or case-specific probability distributions. Furthermore, the concept is not limited to a specific distribution type. The outcome is a risk-oriented and a year-specific distribution over each life-cycle. These results can be used in several ways in the decision-making process. Additionally, the approach provides a useful framework for accompanying risk control systems.

2 Concept of a risk-oriented life-cycle analysis to support management decisions

2.1 Characteristics of life-cycle analysis for decision-making in volatile markets

To design a structured methodical life-cycle approach, the definition of a *workflow* is essential. The basic steps are shown in Fig. 1. In the first step, the risk factors must be identified. This step is discussed in chapter 2.2. Subsequently, all risk factors

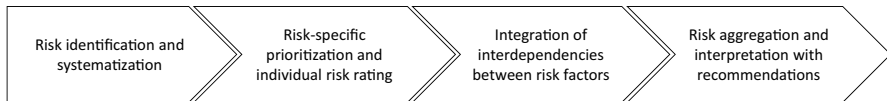


Fig. 1 Workflow for a structured life-cycle analysis

must be ranked and prioritized. For this purpose, chapter 2.3 describes basic assignments. Chapter 3 and Chapter 4 are based on this preliminary work. A simulation approach is used, which allows the integration of dependencies between risk factors for product-oriented lifecycle calculations. The steps are shown for product-oriented life-cycles in chapter 3.2 and for customer-oriented life-cycles in chapter 4.2.

Before methodological details are presented, the paper should be embedded in the research streams and the current state of research. Numerous studies deal exclusively with risk analyses from different points of view and within the management accounting literature. For instance, Braumann et al., (2020), Ittner & Oyon (2020); Posch (2020), Garcia Osma et al., (2022) focused on *risk-oriented control systems* and the convergence of control systems and in internal systems. This is an important task, especially for performance measurement.

For control systems and accompanying risk analysis, well-founded decision-making processes with internal management tools are necessary. In this context, a lot of qualitative management accounting research has contributed to a better understanding of enterprise risk management (e.g. Maffei & Spanó, 2021).

In a *second research stream* many papers analyse the risk-oriented decision-making process under various circumstances. For instance, Lambregts et al., (2021) analyses criteria for decision-making processes under risk in an insurance environment. Bayrak & Hey (2020) analyses different dispersion and skewnesses in risky decision-making processes in a psychological way. One important aspect of such an analysis are *information asymmetries*. For example, Baldenius & Michaeli (2017) analyses the risk-transfer processes. In this case, the decision of responsible persons should be explained.

A *third research stream* arises from a deeper technical perspective, particularly dealing with product-based risk analyses in a technical way (Lahtinen et al., 2021; Vallero & Braiser, 2008). A specific combination of product characteristics has an impact on all subsequent risk-related factors. However, such detailed product-based considerations are not regularly used in managerial accounting to carry out a risk-adjusted valuation process that is structured on a year-specific approach and extends to the overall valuation of the customer relationship. This article attempts to close this gap by using the detailed information that may already be available in the enterprise to carry out a risk-adjusted evaluation of products and customer relationships in order to be able to make a well-founded risk analysis at an early decision stage. Countermeasures can be derived from this evaluation process.

Life-cycle analysis often leads to a product-related profitability analysis, which is aligned to include the positions pertaining to the same decision, even if they extend over time. Therefore, a life-cycle analysis is useful in many cases (e. g. Höft, 1992; Kemminer, 1999; Röser, 2022a). Originally conceptualized in marketing, the

life-cycle analysis offers a transferable structure, which can also be used for several questions in management accounting, e.g., for project calculation, for an evaluation of innovative composite products or for profitability analysis over customer lifetimes. For internal management decisions, we use such methods for multi-period calculations, e.g., during the project or the customer's relationship.

For internal decision processes *four principles* of management accounting are defined in this paper (Troßmann & Baumeister, 2015; Ewert & Wagenhofer, 2006; Riebel, 1994; Kilger, 1961): Principle of Disponibility (PoD), Principle of Relevance (PoR), Principle of Marginality (PoM) and Principle of situative Evaluations (PoE). PoD requires that all positions be assigned to a decision that is also affected by the individual decision. This applies to all positive (e.g., revenues) and all negative (e.g., expenses) effects. Other positions are not allowed to be included in the calculation. In the case of PoR, we have to decide which positions are relevant for the case-specific evaluation process. Positions with no differences between alternatives may be omitted from comparative calculation methods. PoM states that the marginal changes and not average values are to be taken into account. Finally, PoE requires an individual evaluation process of each calculation position in each individual situation. For example, a bottleneck situation requires a different valuation than an unconstrained situation. This paper applies these principles for internal management decisions to a life-cycle approach in risky decision situations.

A life-cycle analysis is informative in several situations. Based on cost considerations, it is useful to distinguish at least *three levels* in life-cycle analysis. The first level of life-cycle analysis is aligned to separately evaluate an *individual product*. The product life-cycle spans the time from initial research to the time at which support for customers is withdrawn. The second level evaluates the *product types*. This allows, for example, making recommendations on the further development of a whole product series over time. The third level extends the product-oriented life-cycle view and tries to assess the entire *customer relationship*. Customer life-cycle considerations refer to the analysis and reporting of customer costs and customer revenues over time. Managers need to ensure that customers contributing sizably to the profitability of an organization receive a comparable level of attention from the organization.

For enterprises, it can be useful to take all levels of life-cycle analysis into account. In this context, a prior product life-cycle analysis is necessary for evaluating customer life-cycles at an upper level. Therefore, the distinguished levels may not be seen independently in each case. Rather, it is seen as a step-by-step process.

The extensiveness of methodological support with life-cycle analysis also depends on *enterprise size*, e.g., major corporations vs. family firms (Hiebl et al., 2018, 2019). A standardized risk analysis is rarely made, especially in small or medium-sized enterprises, and in fact, even single risk factors are only analyzed occasionally in an *argumentative* rather than in a *quantitative* manner. For instance, knock-out criteria are often based on historical costs and methodologically poorly substantiated risk premium indicators. This can even tighten the risk situation. If order-fulfilments have to be provided in foreign markets, country-specific risks additionally overlay the general project risks. Therefore, in negotiations for a foreign order, the risk-adjusted contribution margin has to be calculated.

Management resources are limited, and thus so far, there is no adequate life-cycle tool in management accounting to handle risk analysis under such circumstances. To use standardized methods, e.g., from the risk management of mass-producing and large enterprises, application-premises are often missing for small- or medium-sized enterprises. Such specifics must also be reflected in the methodological risk approach.

2.2 Systematization of risk factors in life-cycle analysis

In a risky decision, we have enough arguments to construct a *probability distribution* for the outcomes. Several concepts for *risk systematization* have been proposed (for an overview, e.g., Crouhy et al., 2001; Pitt, 2004). A useful approach is the distinction between cause-related and effect-related risk analysis (Baumeister, 2008; Röser, 2022a). Figure 2 shows the classification with the corresponding subcases.

In a *cause-related* risk systematization, risk-influencing variables of the respective risk situation can be identified as *risk drivers* or *risk factors*. The interaction of risk drivers is one reason for upcoming problems involved in evaluating life-cycles. Risk drivers can be distinguished by their *place of origin*, whether they are the result of the enterprises' own decision or whether they can be primarily justified by external drivers. *External risk drivers* are outside of the decision-making scope of the enterprise. Figure 3 shows examples of external risk factors. External risk drivers can be differentiated into *framework condition-specific* and *market-related* influencing variables. Framework condition-specific risks relate to actions by external stakeholders that are not directly aimed at the exchange of goods between enterprises. For example, new laws due to stricter CO₂-emissions or new property rights of competing enterprises (patents, utility models) can influence the decision-making situation. Market-related risk factors represent the exchange relationships of the company's goods with procurement markets on the one hand and with sales markets on the other. In principle, these risks can appear in the market price and the quantity structure.

In contrast to external risks, *internal risk drivers*, which are located in the decision-making scope of the enterprise, can be subdivided according to the sub-functions of the enterprise. They can arise in primary functions or in management area.

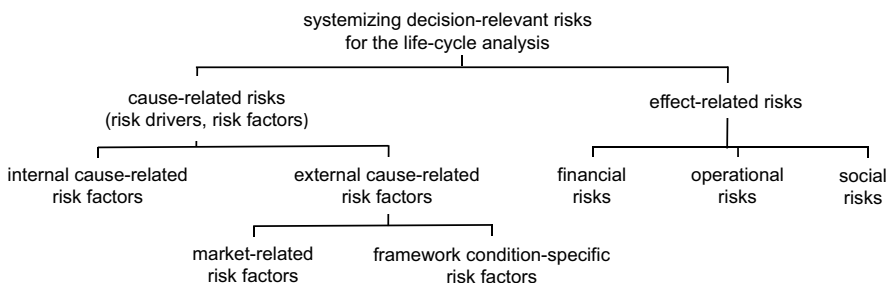


Fig. 2 Classification of different risk types for the life-cycle analysis

External risk factors for life-cycle analysis:

(These factors are outside of the decision-making-scope of the company.)

- **market-related risk factors:**
 - market entry of a competitor
 - special complaint behavior / clumsy handling with the product
 - being part of a critical customer group
 - changes in customer preferences
 - untypical proportion of pioneers in the customer group
 - special currency situation in the market of the customer group
 - special dependencies on upstream trades / cooperation partners requiring upstream services
 - untypical hypothesis about the quantitative market trend of the product
 - untypical behavior of debt capital provider in the case of a loan extension
- **framework condition-specific risk factors:**
 - sustainability requirements
 - specific emission requirements
 - legal safety requirements
 - untypical disposal obligations
 - untypical ergonomic requirements
 - property rights

Fig. 3 Examples of external risk factors in life-cycle analysis

Internal risk factors in life-cycle analysis:

(These factors are within the decision-making-scope of the company.)

- **Machine and plant design, which lead to special features in the creation process:**
 - high proportion of new construction components
 - establishment of a new type of a functional structure by the enterprise
 - imprecise formulation of the requirements before and during the project awarding process
 - untypical or novel combination of several components
 - untypical system elements
 - development of an untypical and new solving process for the enterprise
- **Determinations that lead to special features in the procurement of the required input goods:**
 - difficulties in the procurement of rare input goods
 - use of materials with special storage requirements
 - use of materials with special training requirements for personnel
 - use of materials with special transport requirements in procurement
 - deviating number of specified suppliers as cooperation partners / procurement networks
- **Determinations that lead to special features in the manufacture process of the product:**
 - use of innovative materials with unknown specifications
 - use of input materials that require additional machine equipment
 - untypical construction features
 - untypical number of product components
 - implementation of unfamiliar components and processes
 - special precision requirements for machines and plants
 - special dependence on upstream trades and suppliers
- **Determinations that lead to special features in the logistic process:**
 - high proportion of fragile components
 - untypical construction dimensions
 - international transport with special customer regulations
- **Determinations that lead to special features in the sales process:**
 - special training for the sales staff, especially on plant-specific product features
 - special packaging requirements
 - special dimensional requirements due to commercial regulations
 - features of requirements, invitations to tender and subsequent drafting of contracts
- **Determinations that lead to special features in the customer usage process or the customer relationship management:**
 - special support services during the customer usage process
 - customer contact frequency
 - customer repurchase rate
 - possibilities of exploitation of further services and other accompanying products
- **Determinations that lead to special features in the disposal phase of the product:**
 - poor decomposability of the product
 - use of lower-cost feedstocks with shorter service intervals

Fig. 4 Examples for internal risk factors in life-cycle analysis

Figure 4 shows typical examples of internal risk factors in life-cycle analysis. The primary functions can be distinguished in the operational production sector and the financial sector. In the management area, the typical management functions can be separated, such as goal-setting, planning and monitoring. In the real-goods area, certain orders can entail risks, such as shortfalls in quantity, quality or transport risks and delivery failures. A distinction can be made between procurement, production, sales and financial risks. In addition, there may be peculiarities in the customer use and disposal phase, for example, due to poor demountability of a machine or due to the use of materials with an atypical service interval. Therefore, further risks are added in the customer usage process.

In addition to the causes of risks, it is also possible to take a closer look at the predicted impact of risks. In this case, the risk is determined by the *case-specific goals*, which can be financial, operational or social. A change in the risk burden is always reflected in a change in the probability distribution of one or more parameters. Normally, a *pluralism* of several objectives must be assumed in day-to-day business, and the isolation is not easy at all. For example, a rejection rate can have an impact on the objective of the whole enterprise, but at the same time, it can also influence the achievement of the formal objective. Similarly, a sales transaction may affect both a formal and a social objective.

2.3 Configuration principles for risk-oriented life-cycle analysis

For goal-oriented risk consideration in life-cycle analysis, two aspects should be defined. First, the *space of possibilities* must be delimited adequately. The four principles must be observed in a stepwise way. Second, the goals must be specified over the formulation of a *decision rule* (Balachandran, Balakrishnan, & Sivaramakrishnan, 1997; Holmström & Myerson, 1983). Only variables which decision relevance may be considered (PoD). Usually, the probability profile of the target variable is processed using one or more *indicators*. Therefore, common *risk measures* are also used in life-cycle analysis. This includes always a loss of information. The use of risk measures to simplify risk assessment should always be balanced with the associated consequences in the individual decision situation.

The type of risk measurement is a useful criterion that is oriented to the objectives of the decision maker. The approach can be differentiated according to this criterion, whether they are aimed at the entire probability distribution or only for a part of it. If we look at the entire probability distribution of the target variable, it must be specified whether the risk measurement is reference-point independent or reference-point dependent. *Reference-point independent* risk measurement means that the riskiness is measured by possible deviation from a predefined value. *Reference-point dependent* approaches describe a probability profile of the target variable that is compressed into a risk measure. The deviation of the target variable is defined as a reference point. In the case of *distribution-constrained* risk measures, the negative and positive deviations from reference points are addressed. Typically, a distinction is made between *downside* and *upside* risk measures (Crouhy & Galai 2001).

Regardless of the risk measurement used, the question that arises by considering risk objectives is how to incorporate them into the *decision-making process*. On the one hand, the risk target can be included directly in the *target formulation*. For a whole series of separate risk measures, however, a corresponding risk objective can also be formulated as a *secondary condition*. For example, a decision maker could demand that the probability of a certain unfavorable situation occurring, such as a loss or a project failure, may not exceed a specified level.

There may be reasons to map the *entire probability distribution* for risk assessment. This is especially important if the overall risk is calculated from different (risky) sub-variables. In this situation a further loss of information can be expected. The use of the entire target variable also means that a certain calculation and analysis effort is expected for the constructor and the decision maker. This can be classified as a typical trade-off decision between further information aggregation in a risk-adjusted indicator (with the associated loss of information) and higher exploitation of management capacity. Especially in this case PoM is important. At this point, it may be advisable to formulate an exception that treats standard cases in a more general way, while essential cases are handled in a more detailed structure. Such exemptions are useful to operate in a goal-oriented manner with scarce management resources. In any case, such information should be summarized in internal life-cycle reports with standardized risk-oriented checklists.

3 Conception for risk integration in product-oriented life-cycle analysis

3.1 Structure of risk integration in product-oriented life-cycle analysis

In this chapter, we focus on *product-oriented* life-cycle analysis. First, we have to evaluate each product and, subsequently, in the second step, the entire product type. Generally, all risk factors that affect the individual product should be considered in the evaluation process. Life-cycle analyses for each product track and accumulate revenues and costs for all business functions across the entire value chain from a product's initial R&D to its final customer service and support. Using life-cycle budgeting, managers estimate the revenues and costs attributable to each product from its initial R&D to its final customer servicing and support in the marketplace (Bhimani et al., 2019, p. 366). One important question in life-cycle analysis is whether a product should be manufactured or it is too risky under the anticipated conditions. In exceptional cases, it may even be too risky to sell a product that has already been produced, e.g., in the pharma industry. In this case, the follow-up costs overestimate the expected revenues in later periods. Figure 5 shows the connection between both life-cycle concepts (Troßmann, 2018; see also Röser, 2022b).

When several products are offered as a product package, additional aspects are relevant for risk analysis. Such products are also known as *composite products* or *product bundles*. In these cases, cross-subsidization can occur not only over time but also immediately in the product bundle itself.

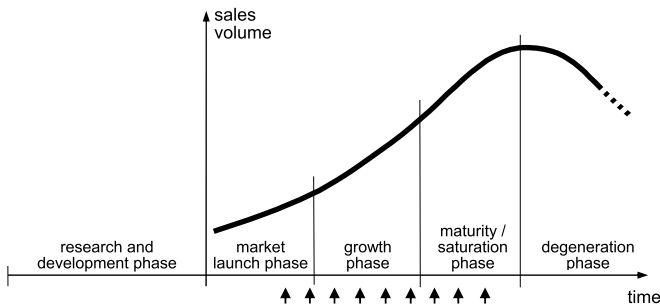
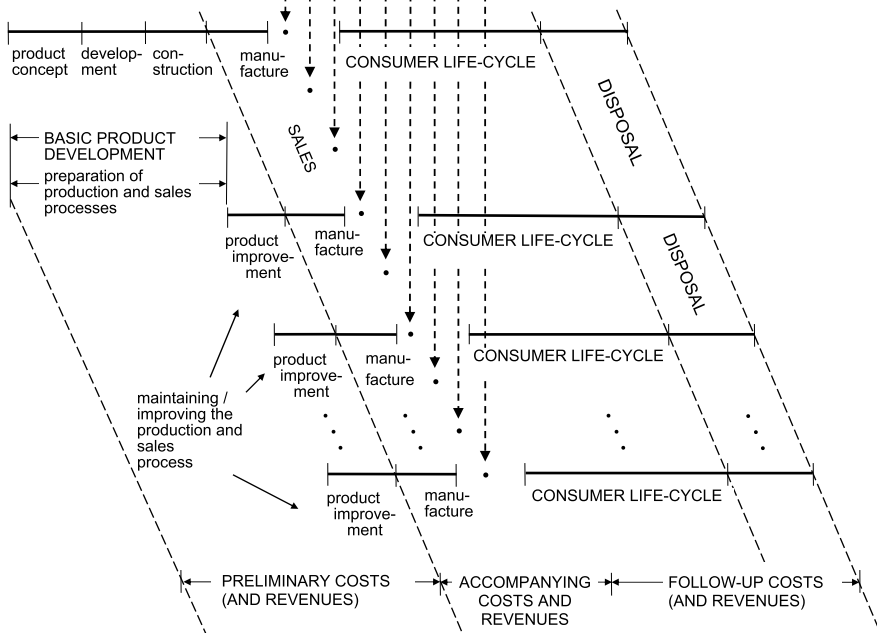
MARKET LIFE-CYCLE:**PRODUCT LIFE-CYCLE:**

Fig. 5 Connection between market- and product-oriented life-cycle concepts

Innovative product bundles usually involve higher risk factors. However, such (still unfamiliar) product combinations are also useful to shift risks from one component to another. At the end, the enterprise charges a selling price per package.

With an increasing product bundle, risks are also transferred from the customer to the manufacturer (Röser, 2022a). For example, if customers buy a varnishing plant, they have to cover the risk of machine failure, lack of spare parts, electric support, adequately trained personnel, execution of repairs and corresponding maintenance services. If someone no longer buys the painting machine from the supplier but

rather the painting of products, then the supplier has to cover the risks. It is necessary to have alternative solutions, but these solutions are only realized in case-by-case situations. Such an alternative can be very cost-intensive. However, the probability of each case can be very low. In this situation, it cannot be fully reflected in the price of each composite product. It is more likely to include this aspect as a *risk premium* in a multi-period decision approach.

3.2 Consideration of risk factors in product-oriented life-cycle analysis

A closer look at the risk-oriented literature and in practice postulates that average positions are often assumed in calculations (e.g., Kumar & Reinartz, 2016; Petersen & Kumar, 2015). In such cases, the risk is regularly based on a generalized risk-oriented *correction factor*. For example, this is a common assumption in capital budgeting decisions. The decision maker assumes a very common situation. In this case, "risk" is considered by a generalized risk reduction factor. The more uncertain the situation, the larger this amount should be. In such calculation approaches, the parameter can also be interpreted as a *risk buffer*. There are several ways to implement such risk adjustments. On the one hand, cash inflows can be directly reduced by an amount and/or cash outflows can be increased due to risk adjustments. The correction factor can also affect the *lifetime forecast*. Therefore, the duration is estimated to be shorter due to the risk report. This approach contradicts PoM and PoE. Risk correction can also affect *interest rates*. Several justifications are given for this approach—also for internal decision-making purposes—such as the risk adjustment of the equity costs using the Weighted Average Cost of Capital (WACC) based on the Capital Asset Pricing Modell (CAPM) (Friedl et al., 2022, p. 188; Manosuthi et al., 2021, p. 462; Mödritscher, 2008, p. 214; Roemer, 2007, p. 446 ff.). In all cases it is an average consideration and contradicts PoM and PoE.

Following a decision-oriented evaluation, the *case-specific risks* should be calculated in a *period-specific* but also in a *product-* and *sales-year-specific* way. Therefore, we should distinguish different risk categories. If the respective risk costs are not based on the nature of the cost unit, they would be allocated as *overhead costs of the unit* to the corresponding cost centers if a corresponding dependency can be identified. It would contradict the *internal decision-making principles*, for example, if the machine failure risk is distributed as a special cost category on the individual product (PoE). At this point, a *hierarchical cost structure* is necessary that includes an exact distinction between fixed and variable costs. One more aspect should be mentioned: In decisions for less important products or customers, a generalized structure seems to be acceptable for the decision maker. However, the more important the case is, the more problematic the assumption will be.

From a principle-oriented management accounting perspective, a generalized consideration of individual parameters is not acceptable. Regardless of the importance of the decision, one attempts to represent the target effect by means of an unsubstantiated average risk value. Such an approach violates the *PoM*. Consequently, the corrections cannot be appropriate even in the case of extreme caution. In addition, it should also be checked whether simultaneous changes in several

parameters lead to a *double counting* or to a *weakening of several effects*. Substantially, the interest correction would even mean a changed assessment of the alternative situation. All these reasons confirm a risk consideration that is associated with a whole series of consequences. Therefore, such approaches should be rejected for internal decision-making, although they are frequently used in practice.

For all these reasons, we need a framework that allows a *period-specific* but also a *product-* and *sales-year-specific* risk measurement approach. For such an approach, a few steps are necessary to fulfil the principles. First, we have to identify relevant risk factors. Standardized risk checklists are often used to support this process. Afterwards, we define the probability functions for each risk factor. Different function curves are conceivable, whereby a normal distribution are often assumed (e.g., Crouhy et al., 2001; Markowitz, 1959). After this step, we have to integrate dependencies in terms of factual and temporal nature. In this approach, both dependencies can be taken into account. Each risk factor is adaptable for each calculation position in each period. This can lead to overlapping risks over time. If all dependencies are mapped in factual and temporal terms, the partial risk-adjusted distributions must be aggregated to a target size. Figure 6 summarizes the risk aggregation steps in a conceptual way.

If we want to predict suitable probability distributions and relationships of the individual computational components, a formula-based determination of the target variable distribution can fail. A way out of this situation is a *simulative approach* (Hertz, 1964; Evans & Olson, 2002; Rubinstein & Melamed, 1998). In principle, this experimental concept is independent of the operating details and can be applied to a wide variety of situations. The method is independent of the function type and case-specific particularities. Simulations consist of several runs (Hertz, 1964). In each run, a characteristic is selected from each component. These aspects enter into the calculation as a random variable. With these input data, the corresponding result value of the target variable is determined. Some simulation steps are necessary. These steps are summarized in Fig. 7.

3.3 Case-study for risk integration in product-oriented life-cycle analysis

The utilization of the risk-adjusted life-cycle approach is illustrated in the following *case study*. It illustrates a standard case of a composite product. To avoid mixing multiple effects, a constant calculation interest rate is assumed. Table 1 provides an overview of important background information for the case study.

In the case study, we consider a car sale process included a mobility guarantee as product bundle. A large part of the manufacturing expenditure is incurred in the period before sale. For reasons of sales policy, the mobility guarantee should only be offered at a comparatively low surcharge at market launch (penetration strategy). Assuming that the conditions are fulfilled, such as compliance with the maintenance and service intervals and the performance of repairs by authorized specialist workshops, the customer benefits from the comprehensive range of services offered by the manufacturer. This comprehensive package supports him, for example, in the case of a breakdown or an accident. The *mobility guarantee* includes a number of

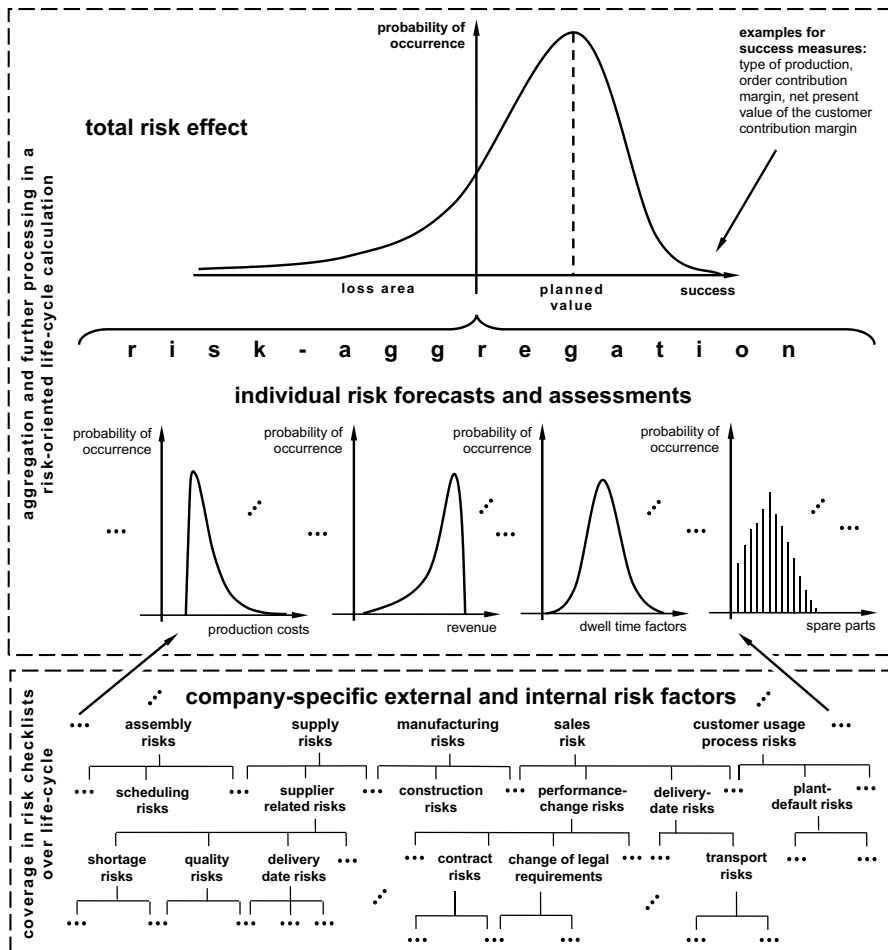


Fig. 6 Steps in a product- and year-specific risk management approach for life-cycle analysis

services. In addition to a connected car package and a repair service, each can be offered independently. The core services include regular maintenance by specialist workshops, an advice and emergency hotline, breakdown assistance with recovery service, provision of a replacement car, and return pick-up service from abroad.

The mobility guarantee as a service bundle is to be offered at an introductory price of 650 €. Half of this amount will be payable in each of the first two periods. The market analysis has also shown that customers would accept an annual price increase from the second year. Sixty-five percent of all customers will take out the mobility guarantee. The manufacturer anticipates declining sales in the last year. To counteract this effect, the price for the mobility guarantee is to be reduced again in the final year of the planning horizon.

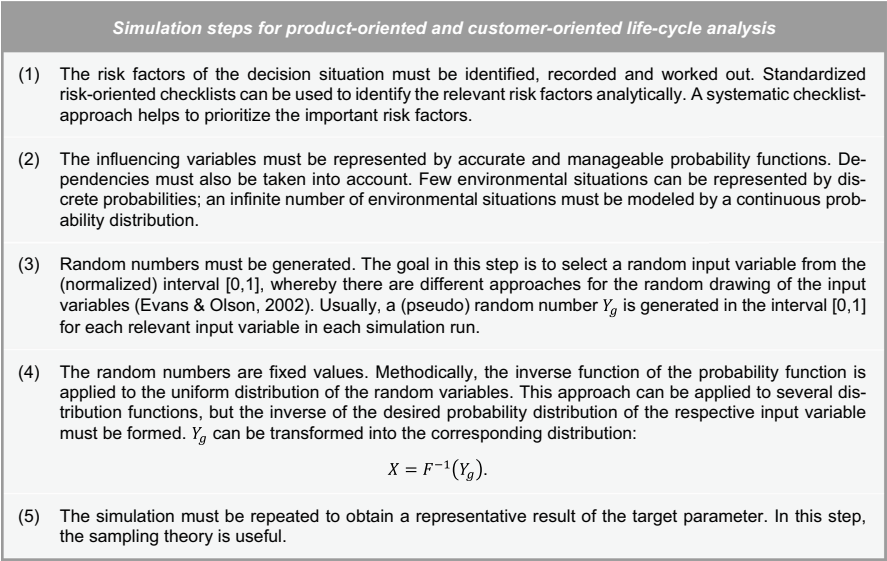


Fig. 7 Simulation steps

Table 1 Basis information for the case study

Parameter	Value
Interest rate	8%
Product-oriented planning horizon	6 years
Market-oriented planning horizon	5 years
Initial price of mobility guarantee	650 €

The warranty is valid for 2 years from the date of delivery. The warranty covers any technical problems that can be traced back to production and/or material defects. The prerequisite for claiming warranty services is the fulfillment of all conditions of the car manufacturer.

In addition to warranty claims, repairs may also be needed; for example, wear and tear of parts is not covered by the warranty. This includes, for example, windshield wipers, exhaust mufflers, batteries for remote controls, wheels, shock absorbers, spark plugs and brake pads. The development department assumes that a warranty case occurs in one of ten cars in the year of sale, in 8% in the year after the sale and in 4% in the following year.

The mobility guarantee also includes a telephone support and an emergency hotline. These services are available around the clock. In general, the hotline serves as the first point of contact in the event of every vehicle problem. A support team can access the vehicle’s on-board computer. Minor problems can be identified, clarified and resolved immediately. The service center can be contacted by phone or manually by pushing the button. In addition, the manufacturer

uses data-transmitting sensors to detect airbags that are triggered by an accident as soon as possible. If this case occurs, an automatically generated message will be transmitted to the switchboard, which contacts the car driver immediately. If the driver cannot be reached even after a few repeated calls, an emergency signal is triggered. The service can also be activated for customer-specific questions, for example, about vehicle operations. If the problem cannot be solved by phone, the mobility guarantee also includes a breakdown service. The car manufacturer keeps appropriate breakdown and towing vehicles, trained personnel and workshop capacity on hand. Depending on requirements and availability, roadside assistance from certified authorized partners can also be requested.

Minor defects can be solved directly. Major problems with cars have to be repaired in the service center. Breakdown services involve cases of varying severity. Since they are associated with different levels of expenditure and case frequency, it seems appropriate to record them separately in risky situations. For this reason, a distinction should be made between minor breakdowns (standard case) on the one hand and more heavy breakdowns (special case) on the other. The first case comprises easier breakdowns that can be repaired quite quickly, such as defects in the car battery, tyre punctures, control problems or defects in the sealing system. The remaining defects are more serious. Therefore, such tasks are assigned to the second group. These include, for example, defects in the engine, defects in the injection system and the vehicle sensor system, defective cooling systems, and serious breakdowns in the fuel system and the fuel pump. Such breakdowns require longer failure analysis, and they are also associated with higher expenses.

Two-thirds of all cases are minor breakdowns, i.e., standard cases. The second cases, as the dwell time factors also shows, occurs less frequently overall, most likely in the last years of the planning period. The *dwell time factor* $v_{z,\tau}$ is generally defined for a cash flow position z in period τ . This factor shows the frequency of occurrence and thereby how many occurrences of z after τ -periods are to be expected.

To estimate the frequencies as well as the expenditure amounts of the two cases, breakdown statistics are useful. From experience, 1.5% of all vehicles breakdown in the year of sale, 4.5% in the following 3 years, 6% in the fourth and fifth years, and finally 9% from the sixth year onward. These frequencies can be divided according to the case frequencies. If the repair of the vehicle takes a longer period of time, a replacement vehicle is provided to the customer. Usually, 5% of all customers with a mobility guarantee use the service in the first three years. Afterwards, the annual take-up rate is expected to be 7%.

The mobility guarantee is supplemented by a *pick-up service from abroad*. This case rarely occurs, but an occurrence releases very high costs for the manufacturer. In approximately 0.04% of all customers with a mobility guarantee in the year of sale this case occurs, 0.05% in the following 3 years and just 0.06% in the subsequent periods.

All risk factors can be represented with different distributions. In the case study, the risk factors are represented by a *triangular distribution*. The triangular distribution is a continuous probability distribution with lower limit a , upper limit b

and mode c , where $a < b$ and $a \leq c \leq b$. In the case study, the triangular distribution (Bronstein et al., 2007) is defined as $F(x)$:

$$F(x) = \begin{cases} \frac{(x-a)^2}{(b-a)(c-a)}, & a \leq x \leq c \\ 1 - \frac{(b-x)^2}{(b-a)(b-c)}, & c < x \leq b. \end{cases}$$

The expenses for the pick-up service from abroad fluctuate strongly. Therefore, this factor will be selected as an important example for a detailed risk analysis. Table 2 summarizes the parameters predicted by automobile manufacturers for pick-up services from abroad.

These parameters can be used to calculate the marginal values of the distribution function for the consequent “pick-up service from abroad”. In the best case, the cost position is 19.50 €; in the worst case, it is 170.50 €.

To generate more information, a distribution function between these boundaries can be simulated. An exemplary simulation run for the component “pick-up service from abroad” leads to the results in Table 3. After 10,000 simulation runs, we derive the frequency distribution in Fig. 8. This figure can be used to estimate the range of costs under the assumed risk factors. If the upper and lower limits are inserted into the risky function, the function’s margins can be defined. In an optimal case, for example, the resulting capitalized costs are €15.23.

A detailed risk analysis would also be applicable to all other components in the life-cycle analysis. Every factor can be risky, not only cash flows but also dwell time factors and/or interest rates. Table 4 summarizes the remaining parameters for the life-cycle analysis in the case study.

With this information, the product- and risk-oriented life-cycle calculation can be finalized. Table 5 illustrates the first simulation run. In a periodic consideration, the mobility guarantee is negative. Therefore, at first glance, these services should not be offered. However, a multiperiod and risk-oriented view allows us to justify a further offering of the mobility guarantee. There are two reasons for this effect: On the one hand, the risk factors can change to a more

Table 2 Parameters of the component “pick-up service from abroad”

		Minimum value	Maximum value	Most likely value
		(Parameter a)	(Parameter b)	(Parameter c)
Mobility guarantee				
Pick-up service from abroad	0	4000 €	43,000 €	17,500 €
	1	4500 €	45,000 €	18,000 €
	2	5000 €	48,000 €	18,500 €
	3	6000 €	50,000 €	18,500 €
	4	6000 €	50,000 €	18,500 €
	5	6500 €	52,000 €	19,000 €
	6	7000 €	53,000 €	19,000 €

Table 3 Exemplary simulation run for the component “pick-up service from abroad”

Relative payment-periods and payment-positions for the mobility guarantee						
Payment-position	Relative Payment-Period (2)	Random Number z (3)	Expenses Dwell time factor (4)	Expenses Amount per unit (5)	Total Payment (6)	Present Value Sales period (7)
(1)						
Mobility guarantee						
Pick-up service from abroad	0	0.003525	0.0004	5,362.24 €	-2.14 €	-2.14 €
	1	0.783338	0.0005	29,607.79 €	-14.80 €	-13.71 €
	2	0.585078	0.0005	25,058.16 €	-12.53 €	-10.74 €
	3	0.931864	0.0005	40,282.15 €	-20.14 €	-15.99 €
	4	0.167871	0.0006	15,608.81 €	-9.37 €	-6.88 €
	5	0.628858	0.0006	28,393.44 €	-17.04 €	-11.59 €
	6	0.442181	0.0006	23,463.10 €	-4.08 €	-8.87 €
Net present value of the mobility-component “pick-up service from abroad”;						
	-69.93 €					

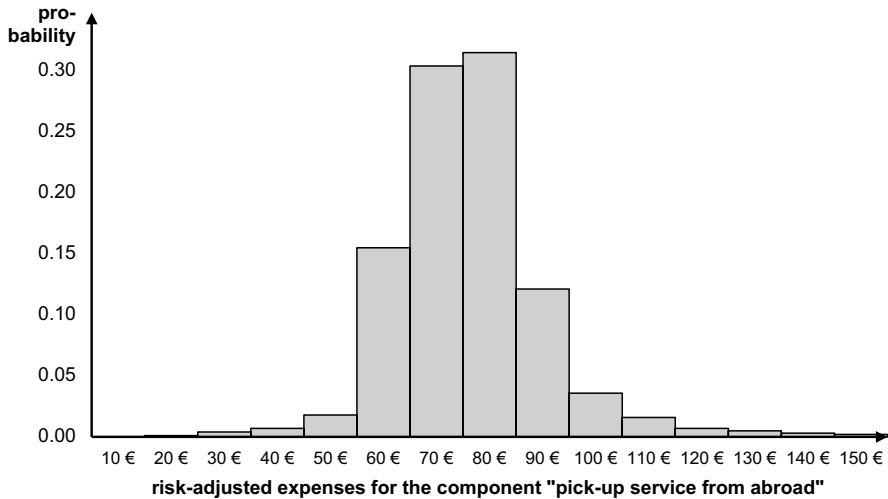


Fig. 8 Distribution after 10,000 simulation runs for the component “pick-up service from abroad”

favorable level, and on the other hand, the mobility guarantee becomes increasingly lucrative over time. Thus, a risk-oriented life-cycle analysis makes a more detailed consideration possible, and with the overall distribution, a more accurate statement can be derived.

After 10,000 simulation runs, we obtain the histogram in Fig. 9. A general overview of the results is helpful to identify which changes within the risk factors are acceptable. Statements can be made about the probability that at least the costs will be recovered.

For the complete assessment of the composite product, the net present value should be calculated. A special feature of the market life-cycle analysis is that the contribution margins of the individual years can be added together after discounting the cash flows. In this way, the capitalized total contribution margin can be expressed across all periods. Table 6 summarizes the market life-cycle analysis with all expected risk components.

In the case study, the project is financially advantageous with an overall net present value of 67,353,406 €. Each risk component enters the computation of the net present value in an indirect or a direct way. In the case studies, all risk factors have an impact on the contribution margin. A change in the risk factors leads to a different result of the net present value over the market cycle.

The strengths and weaknesses of the entire product type can be identified from the individual calculation items. This gives an indication of which components are to be regarded as particularly sensitive to the project success and which components are riskier than others. The market life-cycle analysis allows us to precisely allocate the period-fixed expenditures. Therefore, a period-specific approach is essential, especially for new product bundles.

Table 4 Parameters of the risk-oriented life-cycle analysis in the case study

Risk factors and relative payment periods				
Payment period position	Relative payment period	Risk factors	Minimum value (parameter a)	Maximum value (parameter b)
Primary process	-1			
Production process	0	Production expenses	14,000 €	27,000 €
Repair service	1	Dwell time factor	0.005	0.010
	1	Dwell time factor	0.005	0.010
	2	Dwell time factor	0.100	0.200
	3	Dwell time factor	0.100	0.200
	4	Dwell time factor	0.150	0.250
	5	Dwell time factor	0.200	0.300
Mobility guarantee	6	Dwell time factor	0.250	0.350
Maintenance and service	0-6	Expenses	20 €	150 €
Telephone service	0-6	Expenses	15 €	45 €
	0-6	Expenses	80 €	500 €
Break down service (standard case)	0-6	Expenses	150 €	1300 €
Break down service (special case)	0-6	Expenses	50 €	350 €
Provision of a replacement car	0	Expenses	4,000 €	43,000 €
Pick-up service from abroad	1	Expenses	4,500 €	45,000 €
	2	Expenses	5,000 €	48,000 €
	3	Expenses	6,000 €	50,000 €
	4	Expenses	6,000 €	50,000 €
	5	Expenses	6,500 €	52,000 €
	6	Expenses	7,000 €	53,000 €
Connected-car package	0-6	Dwell time factor	0.650	0.800
				0.700

4 Conception for risk integration in customer-oriented life-cycle analysis

4.1 Structure of risk integration in customer-oriented life-cycle analysis

The risk management literature dealing with customer relationships is still scarce from a managerial accounting perspective. Furthermore, the literature focuses on empirical, highly specialized questions of various kinds (Casas-Arce et al., 2017; Henschel, 2008; Kumar & Pansari, 2016; Petersen & Kumar, 2015; Raman & Shahrur, 2008; Sunder et al., 2016) rather than on a *methodological approach* to risk assessment for customer relationships in an internal way.

In the latter case, abstract design and application recommendations of production classification are usually given independently (Aba Bulgu & Islam, 2007; Alquier & Tignol, 2006). Such recommendations are associated with several restrictions because case-specific aspects are fundamental for risk analysis in customer relationships. For example, an order-based production includes numerous aspects in risk-oriented management, particularly in the calculation for customer relationships, compared to mass-production for the anonymous market. These are caused, e.g., by additional service specifications, resulting in different construction solutions, and by supplementary payment-, guarantee-, and/or supply-agreements. In addition, the offers have to be calculated on incomplete datasets, e.g., quantity structures substantiating the calculation can only be put in specific terms during the construction process. Subsequently, considerable success risks will follow, especially if later adjustments of the negotiated order-returns are difficult or impossible. It can be assumed that individual aspects have an effect on customer-specific risk factors. Such risks will be fully reflected in the distribution of payment positions, payment amounts per unit, dwell time factors and timing.

The evaluation of customer relationships can start at different levels, depending on the data available. For example, evaluating a customer relationship in order-based manufacturing may involve selling products directly so that the customer is distinguishable from the enterprise. In other segments, the customers are not visible to the manufacturer. Therefore, standard hypotheses for a customer segment are necessary. Figure 10 shows the different evaluation levels for risk-oriented life-cycle analysis in customer relationship management.

For a detailed risk analysis, it is advisable to start with the customer relationship evaluation at the lowest level. In some segments, for example, in order-based production, just a few customer relationships can make a considerable contribution to the success of the entire enterprise (Röser, 2022a). Therefore, the loss of a few major customers can easily threaten the enterprise's existence. On the other hand, not every customer is valuable over their lifetime. An assessment focusing on the individual customer is more successful where the customer is *visible* and addressable for the manufacturer. It can be advantageous, for example, to prefer a rather risky basic project with a new customer in the Far East sales market to a regional customer standard order because this project can exert a considerable influence on the future customer relationship. In addition, some effects on other customers can be

Table 5 Exemplary simulation run for the risk-oriented life-cycle analysis

Life-cycle analysis								
Payment-position	Relative Payment Period	Revenues Dwell time factor	Revenues Amount per unit	Expenses Dwell time factor	Expenses Amount per unit	Total Payment	Present Value at sales period (8)	Present Total Value at sales period (sum) (9)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Primary function: production and sales								
Production process	-1			1.0000	16,162.58	-16,162.58	-17,455.59	
	0			1.0000	2,200.00	-2,200.00	-2,200.00	
Sales process	0	1.0000	28,000.00	1.0000	1,800.00	26,200.00	26,200.00	6,544.41
Warranty with complaints	0			0.1000	1,500.00	-150.00	-150.00	
	1			0.0800	2,000.00	-160.00	-148.15	
	2			0.0400	3,500.00	-140.00	-120.03	-418.18
Repair service	0	0.0106	220.00	0.0106	88.00	1.40	1.40	
	1	0.0089	350.00	0.0089	140.00	1.86	1.72	
	2	0.1422	500.00	0.1422	200.00	42.67	36.58	
	3	0.1305	550.00	0.1305	220.00	43.05	34.17	
	4	0.1993	750.00	0.1993	300.00	89.68	65.92	
	5	0.2712	950.00	0.2712	380.00	154.57	105.19	
	6	0.3054	1,050.00	0.3054	420.00	192.42	121.26	366.25
Mobility guarantee								
Sales process	0	0.6500	325.00	0.6500	25.00	195.00	195.00	
	1	0.6500	325.00	0.6500	10.00	204.75	189.58	384.58
Maintenance and service	0			0.6500	108.52	-70.54	-70.54	
	1			0.6500	81.40	-52.91	-48.99	
	2			0.6500	118.06	-76.74	-65.79	
	3			0.6500	66.61	-43.30	-34.37	

Life-cycle analysis

[illegible]

Table 5 (continued)

Life-cycle analysis									
	1		0.0500	150.77	-7.54	-6.98			
	2		0.0500	113.05	-5.65	-4.85			
	3		0.0700	177.59	-12.43	-9.87			
	4		0.0700	165.09	-11.56	-8.49			
	5		0.0700	56.40	-3.95	-2.69			
	6		0.0700	156.57	-10.96	-6.91			-47.55
Pick-up service from abroad	0		0.0004	5,362.24	-2.14	-2.14			
	1		0.0005	29,607.79	-14.80	-13.71			
	2		0.0005	25,058.16	-12.53	-10.74			
	3		0.0005	40,282.15	-20.14	-15.99			
	4		0.0006	15,608.81	-9.37	-6.88			
	5		0.0006	28,393.44	-17.04	-11.59			
	6		0.0006	23,463.10	-14.08	-8.87			-69.93
Connected-car package	0	0.8815	98.00	0.8815	85.51	85.51			
	1	0.4103	98.00	0.4103	39.80	36.85			
	2	0.3655	98.00	0.3655	35.45	30.39			
	3	0.5414	98.00	0.5414	52.52	41.69			
	4	0.7396	98.00	0.7396	71.74	52.73			
	5	0.3644	98.00	0.3644	35.35	24.06			
	6	0.9080	98.00	0.9080	88.08	55.51			326.74
Net present value for a composite product (at the sales period):		€6,607.59							

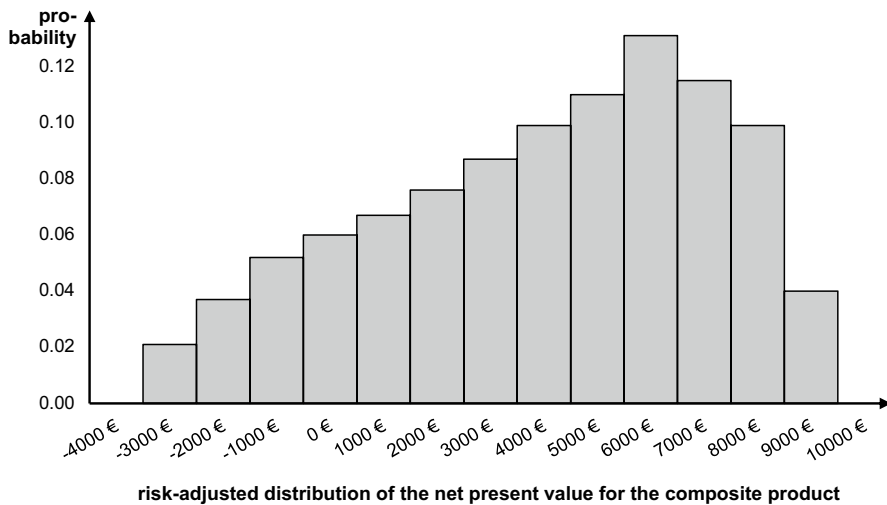


Fig. 9 Distribution after 10,000 simulation runs

assumed, for example, through a positive *verbal recommendation* or a higher *cross-selling potential* (Erat & Bhaskaran, 2012; Ghoshal et al., 2021; Kwiatkowska, 2019; Schmitz et al., 2014). Such connections are well known in the literature. This is one important reason why isolated average period-related customer evaluation falls too short. In such cases, it is necessary to *classify* customer relationships on the basis of customer potential over time. Under this circumstance, the assessment of customer relationships is made more difficult by the fact that particularly in the case of *repeated interaction* between manufacturer and customer, an isolated product assessment cannot be assumed. This aspect leads to a more serious risk situation. A *cross-product view* of the customer relationship becomes an important aspect in the risk-oriented calculation approach for customer relationship management. Such a view is even more purposeful when partial services are offered at sales prices, which are obviously only justifiable because the manufacturer expects the customer to order additional services at a later time. This is an important reason for the manufacturer to lead the customer into a system of a clever designed and usually modularized package. The common element of such a system is the appropriate combination of individual elements for the customer-specific solution. In such a case, the product is offered as a *bundle of matching services*. As a consequence, the scope for decision-making is limited at a later decision stage. Such a system of several individual components is set up not only to cover the customer's current needs but also to identify and address the requirements as exhaustively as possible throughout the customer relationship. In addition, a dependency relationship between manufacturer and customer can arise, and the service bundle extends over time. All these individual elements are typical for *customer relationship evaluation* with life-cycle analysis.

In this context, the valuation of customer relationships is confronted with *factual* and *temporal allocation problems*. In the literature, the *customer lifetime*

Table 6 Market-oriented life-cycle analysis in the case study

Year	01	02	03	04	05
Contribution margin	6,607.59 €	6,977.24 €	7,074.88 €	7,192.06 €	6,895.87 €
Sales volume	10,000 pcs	30,000 pcs	27,000 pcs	20,000 pcs	11,000 pcs
Gross contribution margin	66,075,944 €	209,317,130 €	191,021,817 €	143,841,109 €	75,854,540 €
./. Research & development	-40,000,000 €				
./. Fixed expenses of the manufacturer process	-60,000,000 €	-80,000,000 €	-80,000,000 €	-80,000,000 €	-70,000,000 €
./. Advertising expenditure	-3,000,000 €	-2,000,000 €	-1,000,000 €	-1,000,000 €	-1,000,000 €
Annual contribution margin					
- Current value	-30,924,056 €	127,317,130 €	110,021,817 €	62,841,109 €	4,854,540 €
- Present value	-28,633,386 €	109,153,918 €	87,338,865 €	46,190,091 €	3,303,918 €
Net present value over life-time			217,353,406 €		
./. Start-up expenditures			-150,000,000 €		
Net present value over the market cycle:			67,353,406 €		

value is regularly proposed as a key performance indicator to solve such problems (Baidya et al., 2019; Berger & Nasr, 1998; Bursk, 1966; Gupta et al., 2006; Hoekstra & Huizingh, 1999; Jackson, 1985; Kotler, 1974; Kumar, 2018; Kumar & Pansari, 2016; Pfeifer & Ovchinnikov, 2011; Rust et al., 2011; Sunder et al., 2016; Venkatesan, 2004; Zhang et al., 2016). This measure can be interpreted broadly, but the approach is often connoted with *limiting hypotheses* (e.g., Heldt et al., 2021; Roemer, 2007). In particular, standard assumptions can fail in risk analysis. For example, the calculation approach regularly assumes that the associated consequences are completed within the sales period. In addition, average costs for each customer relationship are assumed (Heldt et al., 2021; Méndez-Suárez & Crespo-Tejero, 2021), and sometimes the cash flows are corrected by different factors that attempt to take the average risk into account. Such approaches only seem to make sense if no *cross-period consequences* are to be expected, if a regular sale of constant products is to be assumed and if no more accurate forecasts seem to be possible. In the standard case, such a limited situation does not exist. In contrast, in many cases, a detailed information basis about customers is available. At least the experts, for example the engineers, the sales representatives and the managers, can specify certain parameters as a bandwidth for the relevant values. Therefore, it does not seem reasonable to include only standard assumptions. Moreover, for customer analysis, the product-related information examined in the previous chapter is useful. These analyses should be supplemented by customer-related risk factors. In this case, several payments will overlap over time (Röser, 2022a).

4.2 Consideration of risk factors in customer-oriented life-cycle analysis

A risk-oriented calculation approach for the customer relationship should include all relevant year-specific risk parameters. One aspect is the modeling of dependencies between products over the customer lifetime. For example, after successful project completion, a follow-up project is scheduled. Such a project, which will be executed at a later date in the customer relationship, can be handled by the plant manufacturer itself. The *probability* of obtaining the follow-up project is related to the previous experiences from the customer relationship, so this case cannot be seen independently of the previous *interaction process*. Successful implementation of the initial project increases the allocation probability for the follow-up project. *Conditional probabilities* enable it to appropriately represent such situations (Röser, 2022a).

The management and the expected costs of customer relationship management depend on customer properties. In this case, customer-oriented classifications are necessary. For example, there are customers who do not show any conspicuous behavior. On the other hand, there are customers who show atypical customer behavior. In the second case, another service process and regularly higher costs are expected. Several customer classes can be justified by the fact that customer relationship management takes place more or less intensively depending on the estimation

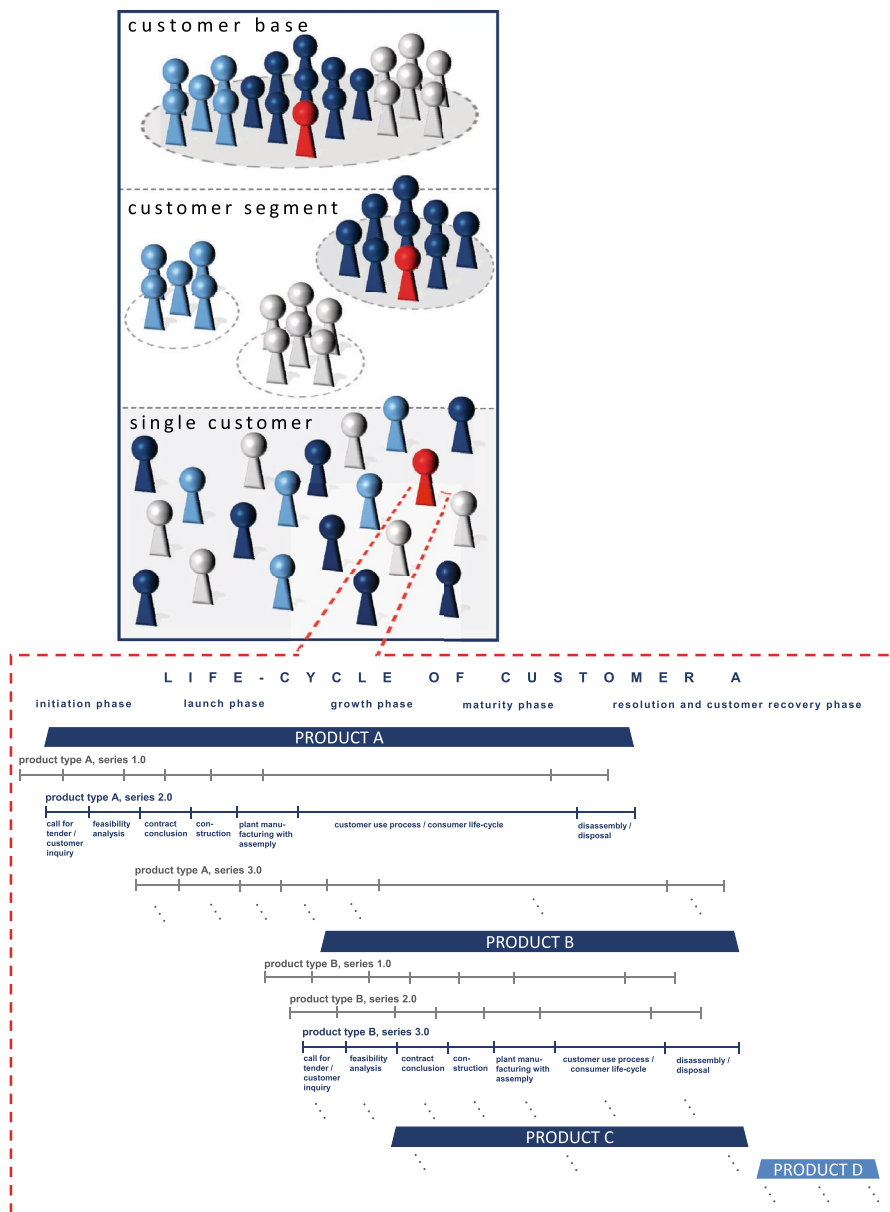


Fig. 10 Evaluation levels for customer-oriented life-cycle analysis

of the enterprise. In addition, the manufacturer wants to intervene at an earlier stage to avoid particularly negative effects, especially by important customers.

The number, expenditure height and temporal occurrence of relationship care must be predicted separately for each class. In this case, another distinction in life-cycle analysis is necessary. The detailed procedure corresponds to the presented risk-oriented approach in the previous chapter.

5 Conclusion

This study integrates the different levels of life-cycle analysis in an adequate way. For a precise customer analysis, a well-founded internal accounting system is necessary, which starts at the individual product level and takes the four principles of internal decision-making processes into account.

The article contributes to the literature in the following ways. First, managing risks, the provision of well-founded risk-oriented analysis and higher risk transparency are essential factors for decision-making processes in volatile markets. A risk-oriented expansion of the life-cycle approach improves the decision-making process, because we can anticipate risk factors in an early stage, we can calculate scenarios and we can analyse multi-period effects in a detailed way. Related to this, this approach enables periodic adjustments, which can also be used for accompanying management scenarios and control systems. This is an important aspect, especially for new composite products. They are offered over a longer period of time and normally they are associated with a riskier situation. A risk-oriented life-cycle analysis comprises such calculation concepts in which payments are made at different points in time. The outcome is a risk-adjusted profitability analysis in a situational way. A bandwidth of the parameters can be estimated more accurately and corrective actions can be initiated at an early stage. In general, the approach is fully in line with the four principles described in Sect. 2.3.

Second, a more comprehensive life-cycle approach can increase the resilience of the entire enterprise. This is due to the increasing information gain and the early consideration of possible risks in the decision-making process. The early anticipation of possible risk factors enables *agile adaptation* for management decisions.

Third, the methodological approach is flexibly adaptable. For example, the method is not limited to any distribution functions, e.g., normal distributions. Therefore, risk-oriented life-cycle analysis can be used to determine the advantage of composite products or customer relationships. Different risk factors and additional information can be considered in different ways, e.g., expected independencies between several risk factors over conditional probabilities or bivariate functions.

Fourth, a more accurate evaluation of risk factors reduces the number of surprising situations in management processes. Therefore, forward-looking risk management with a risk-adjusted life-cycle approach is essential to mitigate risk in important management decisions.

Product- and customer-specific risks can be reflected in different parts of the value chain. An accompanying risk-oriented checklist is a useful solution to prevent incorrect decisions in life-cycle management. The idea is to separate the description of the current situation and the forecast for future parameters into partial aspects rather than calculating an overall value for each object. Such risk-oriented *checklists* allow a systematic and standardized recording of risk causes, the documentation of implemented risk management for internal and external recipients, the development of a knowledge database for the risk assessment, the design of a structured reporting system, the support of risk management requirements in existing planning and reporting systems and, in most cases, an assignment of tasks. One important aspect during such tasks is a user *interactive risk reporting system*. Additional questions are, e.g., how often the report is initiated, who is responsible for initiating the risk report and what is a relevant exception for management decision-making processes.

Risk reporting have a decision-facilitating and a decision-influencing role in management processes. Thus, several coordinative aspects in risk reporting can be identified, which should also be used in the risk-oriented life-cycle approach. Ultimately, a well-founded methodical instrument can only be convincing if the information is reported in an appropriate manner.

An *anticipative risk reporting system* is necessary for a proactive risk management process. Life-cycle analyses can be integrated into reporting systems. Therefore, the presented methodological approach can form an important basis for a useful management approach to improve resilience in uncertain times.

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Declarations

Conflict of interest The author declares no conflict of interest. No funding was received. Data will be made available on request.

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