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Development of the PRISM risk assessment method based on pairwise comparison

Doctoral (Ph.D) Thesis – Thesis booklet

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Table of contents

1   Relevance of the research and the structure of the dissertation

The management of risks permeates all areas of our lives, from the health issues of our private lives to the risks of supply chains (*Pfohl, 2002*), to the risks of today's circular economies (*Yazdani et.al., 2021*, *Pellegrino, 2025*).

A common feature can definitely be discovered in various risks: we want to protect ourselves (or our organization) from unwanted effects, or if the problem has already occurred, to take possible countermeasures. To do this, it is necessary to be aware of the nature of the risks and to recognize their connections in time. The variety of risks has induced the development of even more types of management methods. Of course, as in other areas of management science, there is no "philosopher's stone" in risk management, a uniform, all-encompassing methodology. Every developed risk assessment methodology carries advantages (whether methodologically or in terms of user-friendliness), but it also struggles with limitations. In many cases, only differences in nomenclature result in a new method, further complicating the work of a risk management professional who wants to select the method that best suits his or her goals.

The fundamental objective of the dissertation is to explore the limitations of the selected risk analysis techniques, identify areas for further development, and then present a possible methodology to address the identified limitations.

The thesis examines the application conditions, advantages and disadvantages of the methodologies selected during the literature research from the perspective of their applicability, with particular attention to their application limitations. Based on the identified limitations, I propose an extension of the PRISM (partial risk matrix) methodology.

In the first main part of the thesis, the literature review, the trends, approaches and methodologies used in practice for risk management are identified. The risk matrix, FMEA (failure mode and effects analysis) and PRISM methodologies are introduced. The focus of the presentation is on the criticism of the application methodology of each technique. The FMEA methodology is a widely used, everyday method, but the RPN number used to classify the risk during its application overly aggregates the nature of the risks, thus giving a distorted picture of them to decision-makers who want to manage risks.

The PRISM methodology, which uses a partial risk matrices, clarifies the distorted picture of the FMEA analysis by evaluating sub-risks in pairs and visually illustrates the importance of each sub-risk, but it does not yet provide sufficient assistance to decision-makers for their actual prioritization and for the actual comparison of risks.

The comparison can be facilitated by the application of various multi-critria decision-making (MCDM) techniques. Among the MCDM techniques, the Guilford method, the AHP and the TOPSIS methods are presented in more detail as techniques suitable for eliminating the disadvantages of the PRISM method.

After presenting and critically analyzing the literature on MCDM methods, I propose a methodology development to expand the PRISM method by combining them with the PRISM method. This is done by developing a combination methodology of Guilford-PRISM, followed by the description of an AHP-TOPSIS-PRISM methodology.

The functionality of the extended methodologies is examined using case studies that describe real risk situations. During the data collection for the case studies, not only the proposed methodology but also the previously applied risk management procedures at the organization providing the case are briefly presented, and then the applicability of the proposed methodology is examined by comparing the results of the existing and new practices.

To conclude the dissertation, I present the possibilities and a framework for the managerial application of the proposed methodology, and finally I outline further development and extension directions.

The structure of the research process is illustrated in the figure below.
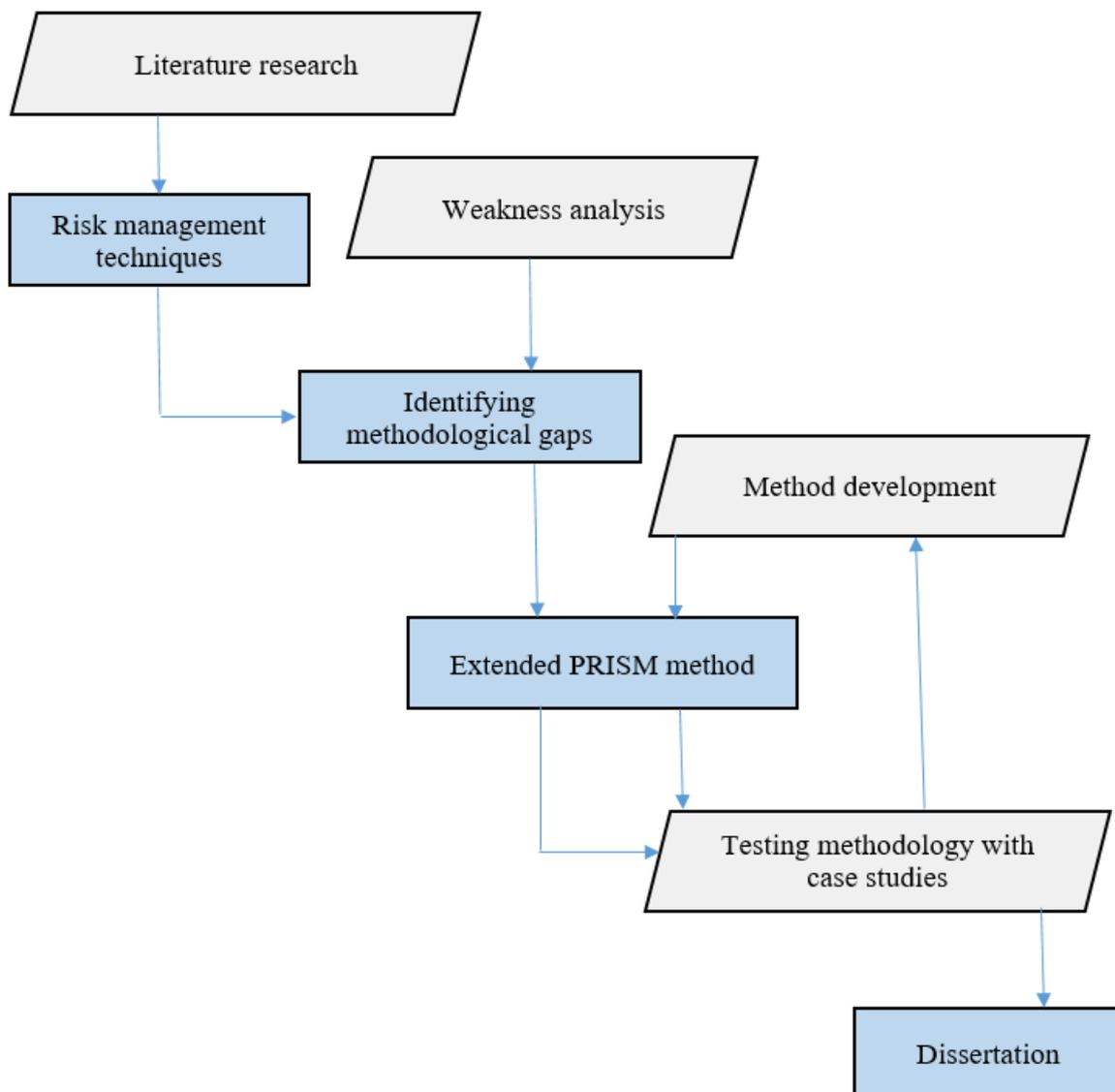
2   The motivation of the researcher, the goals of the research

Based on my experience in management education and research over the past 20 years, risk management is one of the biggest challenges for today's leaders in their work. Their tasks and individual abilities may differ, but if we look for common points in the work of leaders, they basically continue to plan, organize, instruct, and control, as we learned from the great classics of management (Taylor, Fayol) over a hundred years ago. Another commonality is that leaders and managers make decisions, most often based on minimal information, filtered through the lens of their own experience, under risky circumstances. On the one hand, this is where my interest in risk management stems from. Is there a universally applicable method for managing risks?

On the other hand, my experience as an organizer (case study solving competitions, maintenance conferences) also shows that many years of experience help to implement events "routinely", but this also hides countless dangers. Have all relevant factors been taken into account to a sufficient extent for the successful implementation of the event? Have the individual risks received sufficient attention during the organizing process, according to their real weight? Experience is linked to the person. The question is whether it can be transferred? If there is a method that can be used to interpret risks according to their importance, then their management will no longer depend on the person in the sense that subjectivity can be reduced during decision-making.

Maintenance is a strong motivation for me, as it is also one of the prominent areas of risk emergence. In 2025, the International Maintenance Conference was held in Veszprém for the 37th time. The past, which can be measured in decades, influences my life and thinking with countless ideas, traditions, and inspiration. The community, which was based on the reliability theory principles established by Professor Zoltán Gaál at the then University of Veszprém, expanded with plant maintenance ideas by Professor Zoltán Kovács, and called "only" the Veszprém maintenance school by Professor Csaba Horváth, has been nourished with countless defining ideas. Among the thoughts on organizing maintenance, the mass of answers sought to the questions of when stands out in particular. When should maintenance be done? We can easily answer this when it broke down. But when will it break down? This is more difficult to answer. If we can identify which risks (technical, economic, organizational, and human, etc.) lead to failure, we can get closer to the answers. Another big question is whether these individual risk factors are equally important or not in terms of failure, as this can prioritize the tasks to be performed. Nowadays, organizations collect data on everything, including maintenance. Sometimes, we still fail to "see the forest from the trees," because diligent data collection alone is not enough. If there is a data processing and evaluation method that is appropriate for the purpose, for example, for risk management, then the essence can be filtered out more easily, and the always scarce resources can be more easily directed to the purpose in order to manage it. But is there such a risk assessment procedure?

The main question of my dissertation is: what are the limitations of certain risk management methods and procedures, how can those limitations be overcome, if at all? In my dissertation,

I propose an extension of the PRISM methodology of risk assessment by combining it with pairwise comparisons.

The research started from the assumption of what limitations and application difficulties the risk analysis techniques used today have. In addition to their advantages, the widely used techniques struggle with various measurement problems, which can sometimes be described rationally and quantifiably, but cannot always handle individual subjectivity. To solve this problem, several methodologies, and even more extensions and additions, have been created in the past decades of the history of management science. In addition to the need for rationality, the application of pairwise comparison methods and their combination with various risk assessment techniques, which strive to achieve complete information, while also taking into account the possibilities of managing the limitations of decision-makers, seems to be a possible way to reduce the degree of subjectivity.

As a result of the research, my goal is to develop and introduce a risk assessment methodology that organizations can use to reduce evaluator subjectivity while assessing risks, so that the risk ranking(s) using the methodology can provide a clearer picture than their previously used methodologies. A more accurate picture of risks enables the employing organizations to prepare for potential risks more effectively, thus providing them with a more effective decision-making process, and enabling better use of scarce resources when managing risks. This can significantly ease the management work of the employing organizations by making it easier to focus.

3 Literature review and conceptual framework

Risk and its assessment

During corporate operations, we can consider any disruptions or events originating from external or internal sources as risks, which, if they occur, could jeopardize the satisfaction of customer/client needs or the safety of company stakeholders. (*Horváth and Szlávik, 2011*)

In his study, Doff identifies uncertainty as the main characteristic of business risk, and identifies 3 approaches to its management:

- method of analogies: comparison with the practices of competitors (or even internal organizational units), the greatest advantage of which lies in its simplicity;
- statistical methods: identification of trends and volatilities in business operations based on past data, which use methodologies similar to those used in other financial operations, making them easy to use;
- scenario mapping: preliminary mapping and evaluation of individual risk events based on expert opinions, which can also prepare the management of risks. (*Doff, 2008*)

In the areas of corporate operations (operational, financial, human risks), risks can even appear together, and risks attributable to external and internal sources jointly affect the performance of the organization. Hanggraeni et al. (*Hanggraeni et al., 2019*) highlighted in their study that managing risks attributable to external and internal sources may prove to be particularly significant in the lives of small and medium-sized enterprises.

A common characteristic of risks is that the risk itself and its management require a process-based approach: the exploration of the system of causes and effects. Their complexity can be seen – among others – in the fact that individual phenomena and events pose different risks in time, space (for stakeholders) or from some aspect. Essentially, a multi-aspect decision problem (*Rapcsák, 2007*) must be solved in order to manage risks. Several processes and methodologies are available for this, such as the AHP methodology, which can be used to identify risks in sufficient detail.

In his book Sadgrove (*Sadgrove, 2016*) divides business risk management into three main stages: risk identification, risk assessment, and risk mitigation. The main methods that can be used during each stage are discussed below.

Kosztyán et al. provide an example of how to deal with uncertainties inherent in risk measurement in their publication (*Kosztyán et al., 2010*).

Risk Matrix

The risk matrix is a widely used tool in many areas of management for assessing and prioritizing risks. It is mostly illustrated using a two-dimensional, visual representation to assess the risk of individual events, based on their probability of occurrence and the potential severity of the risk. The risk matrix is a semi-quantitative risk assessment method that evaluates risks based on historical, statistical data (*Ni et al., 2010*).

The advantages of using a risk matrix can be summarized as follows:

- the *visual representation* makes the fundamental relationships of risks easy to understand and present to all stakeholders;
- the *ranking* allows the scarce resources available for risk management to be easily reallocated to the most serious risks;
- it provides a clear framework for the *decision-making process* related to risk management;
- it provides a *consistent approach* throughout the entire risk management process for the entire organization. (*Elmonstri, 2014*)

Disadvantages of using the risk matrix:

- The categories of the dimensions are mostly determined ad hoc, making it difficult to compare the individual matrices. (*Cox, 2008*)
- During the mental processing of risks, their classification is mostly based on subjective value judgments, which can make consistent application difficult. (*Ball and Watt, 2013*)
- The scaling of the individual dimensions is usually done on low-level (ordinal) scales, using low-quality data, so their reliability may be questionable. (*Duijm, 2015*)

FMEA

FMEA is a systematic, bounded procedure that identifies the possible failure modes of a product, system or process, thus enabling their management and reduction of their effects. It is

particularly often used to identify risks arising in connection with the examined element. It links the effects to the causes through the failure modes (*Deák, 2005*). The basic FMEA methodology provides a framework system, supports and widely assists the methodologically stable operation of the quality system and, through its application, assists continuous quality improvement initiatives (*Szakály, 2005*).

The FMEA methodology has two basic areas of application: product (design, construction) and process FMEA. System FMEA targets a more complex unit during its application.

The FMEA methodology is a multi-criteria risk analysis solution, which expresses the aggregate characteristics of risks in the form of a so-called Risk Priority Number. During traditional FMEA, each identified failure mode is scored on a scale of one to ten based on three parameters, which are: the severity represented by the event (Severity), the probability or frequency of occurrence (Occurance), and the probability of detection (Detection). By multiplying the three parameters (S x O x D), the RPN number can be calculated, which shows the priority of the given risk in comparison with all other failure modes identified during the analysis (*Andrade et al., 2020*).

Advantages and disadvantages of FMEA (*based on Könyves and Kalló, 2022*)

| Advantages of applying FMEA	Disadvantages of applying FMEA
Widely applicable, regardless of industry, system, process, requirements	Not suitable for identifying combinations of different failure modes
Illustrates problems, shows how the error manifests itself, and shows its impact	Difficult to apply in case of complex multi-level systems
Can also be used to identify and analyze preventive measures, saving time, money, and other resources	Each analysis step consumes a lot of time and costs
Can be used effectively in maintenance and process monitoring	There is subjectivity in the scoring system
Easy-to-understand structure	There is no designated process or step "package" that must be examined in every case, so the selection of failures to be analyzed is also team-dependent

The PRISM method

The FMEA method is useful in ranking the risks of different failure modes and effects, but the methodology primarily focuses on determining the RPN number, and ranks based on it. Since the impact of the 3 dimensions (severity, occurance, detection) is treated as a single value, the values of each dimension can underestimate or overestimate the real importance of the other dimensions. This can be considered a significant problem, since the mathematical operation used during the formation of the indicator (multiplication) can mask the detailed information carried by each qualification factor regarding the actual nature of the risks. Moreover, if we want to compare more than three factors, the multiplication used to calculate the RPN number will consistently underestimate the risks. (*Kovács et al., 2022b*)

The PRISM methodology is recommended, for example, in cases where high reliability of business processes is expected (for example, in the banking sector), or where environmental aspects are expected to be given priority (for example, in the case of a nuclear power plant), or where the organization's safety expectations simply necessitate its application.

PRISM allows the management of risks according to certain dimensions, and according to their real weight, if we describe the partial risks using risk matrices using the following 3 sub-risk matrices:

1. Occurance vs. Severity;
2. Occurance vs. Detection;
3. Severity vs. Detection;

which is illustrated in the figure below.
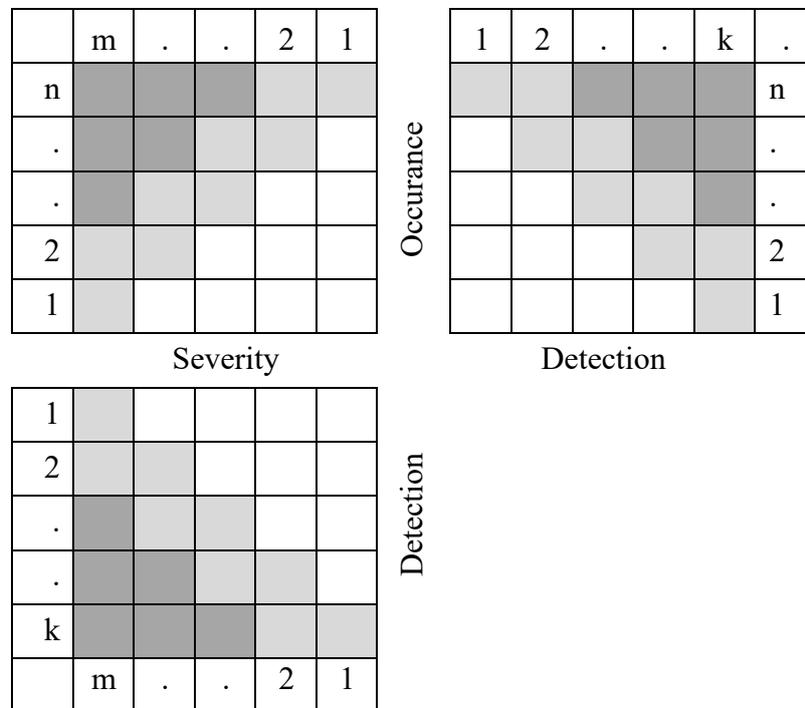
The general model of PRISM, according to *Benedek et al., 2021*

Although the PRISM methodology offers a solution for the detection and management of underestimated partial risks, we cannot forget about the limitations of the methodology. Kovács et al. (*Kovács et al., 2022a*) point out that the methodology focuses on and examines only three dimensions of the FMEA analysis. Another challenge is that the application condition of the PRISM methodology is that the factor weights of the evaluation dimensions are the same, otherwise the results will be biased. The evaluation process is based on deterministic evaluation scales from the nomenclature of novel multi criteria decision methodologies (MCDM) (*Cinelli et al., 2022*). Due to the inflexibility of deterministic evaluation scales, as is the case with the PRISM method, the sensitivity of the data used is crucial.

In summary, the PRISM methodology can be interpreted as a combination and extension of the risk matrix and the FMEA. The aim of the methodology is to describe partial risks that would

remain hidden if only the FMEA or the risk matrix were used. Thus, the methodology provides a more efficient and detailed, overall more accurate picture of the risk assessment result, which may be necessary for compliance-sensitive and safety-requiring systems. Based on the RPN values and the partial risks that may exist, risk mitigation action plans can be prepared and initiated.

Users can adapt the PRISM methodology to the target area of the assessment, and PRISM can be useful when it is necessary to determine the focus of corrective actions. Since partial risks can be identified as a result of the assessment, a more detailed risk reduction measure can be developed.

PRISM is a hybrid methodology that builds on the basic features of FMEA and risk matrix. Based on the parameterization, PRISM can be used as a methodology that relies more on the RPN value during risk assessment, or focuses more on partial risks. Thus, the methodology can be widely customized according to user needs.

Multi Criteria Decision Methods

Multi Criteria Decision Methods (MCDM) is a generic term for a family of methods that help make decisions where multiple, often conflicting, criteria must be met simultaneously. (*Taherdoost and Madanchian, 2023*)

Pairwise comparison is a widely used method, within which one possible method for performing and evaluating pairwise comparisons is the Guilford method (*Guilford, 1928*), in which the preferences between the pairs to be compared are determined and analyzed. Another possible method is the AHP (Analytical Hierarchical Process), which can also be used to examine the strength of preferences (*Saaty, 1987*).

The application of BWM (Best Worst Method) is recommended when the number of factors to be compared is high, while we also want to examine the strength of preferences (*Rezaei, 2015*).

TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) is a multi-factor decision-making methodology that helps to rank different options according to their "distance" from the extreme values of the ones to be evaluated (*Chakraborty, 2022*). It considers the alternative that is the smallest distance from the ideal positive solution and the furthest from the negative ideal to be the best choice or decision. (*Chakraborty, 2022*) The individual intermediate alternatives can be ranked according to their distances from the ideal alternative. (*Hwang and Yoon, 1981, Chakraborty and Yeh, 2009, Chakraborty and Mandal, 2018*)

The combinations of AHP and TOPSIS methodologies have provided new approaches mostly in the following areas:

- the combination of TOPSIS methodology with AHP for determining factor weights and decision-making,
- the development of other decision-making or evaluation methodologies by expanding them with the AHP-TOPSIS methodology,

- various fuzzy techniques are often used when machine learning is at the center of the evaluation, especially in the case when the decision-making problem is considered to be extremely complex (*Forgács et al., 2020, Braglia et al., 2003*).

4 Research methodology

In my dissertation, I described a methodological development to address the shortcomings of the PRISM methodology, which started from the following questions and assumptions.

4.1 Research questions and assumptions

Classical risk management methods, such as the risk matrix and FMEA, offer tempting opportunities for identifying and classifying risks with their prevalence and simplicity. However, like every coin, risk assessment also has a downside. FMEA compresses the risk characteristics into a single value by calculating the RPN indicator, making it difficult to apply in multi-level systems. (*Könyves and Kalló 2022*) The PRISM methodology provides a solution to this problem, which can provide a more visual picture of the risks than the RPN number by managing sub-risks. (*Benedek et al., 2021*)

The weakness of the PRISM method is that it only focuses on the nature of the risks, does not provide a sufficiently detailed picture of their solution directions (*Bognár and Hegedűs, 2022*), does not sufficiently address the difficulties arising from the subjectivity of opinion makers (*Redmill, 2002; Banghart et al., 2018*), and does not examine the reliability of opinion makers (*Benedek et al., 2021*).

Based on the above, I formulated my first research question.

1. *What additions are needed to the PRISM methodology, which would allow the comparability of risks as well as the reliability of the evaluators?*

During risk assessment, expanding the PRISM methodology with various MCDM techniques (e.g. AHP (*Saaty, 1980*), TOPSIS (*Chakraborty, 2022*), BWM (*Rezaei, 2015*)) as described in the literature review may be a viable way to overcome the challenges of the methodology. Like all methodological developments, combining them with MCDM techniques gives the PRISM methodology both advantages and disadvantages compared to the original methodology. This may be reflected in the applicability area (general or specific management/business areas), the nature of the measurement scales, the focus of usability (strategic vs. operational), etc. When qualifying the "goodness" of the development, all of the factors listed above must be taken into consideration in the decision of the manager choosing a methodology for risk assessment.

Based on the above, I formulated my second research question.

2. How can the expansion of the original PRISM methodology with certain MCDM techniques provide a methodological solution to decision/risk management problems arising in a given application area?

Pairwise comparison techniques, such as the Guilford method (*Guilford, 1928*) or the AHP (*Saaty, 1987*), aim to fully organize the elements (risks) under consideration so that they can be evaluated appropriately, based on the widest and most accurate information possible. This can pose a significant challenge to those involved in the evaluation. If we want to receive the most accurate and reliable evaluation from risk assessment professionals regarding the nature of the risks, then it is necessary to help and support them in their evaluation work. The PRISM method is a clear, easy-to-learn, and applicable tool. When applied, the evaluators prepare the rating as a real group, in the context of actual joint thinking (*Bognár and Benedek, 2022*). Group work with personal participation can distort individual opinion formation, as dominant individuals (either from personal sources or from the position provided to them by the organization) can influence opinion formation. However, the PRISM methodology does not examine the agreement or distortion of expert opinions.

Based on the above, I formulated my third research question.

3. How does the use of pairwise comparisons change the PRISM risk assessment process?

After setting my research questions, my assumptions follow, their numbering follows the research questions.

<u>Assumptions</u>:

1. If the PRISM method remains suitable for risk management even after integration with various pairwise comparison techniques, then the pairwise methodologies will also allow for the examination of expert consistency (with a lower number of cases).

2. When combining the PRISM methodology with pairwise comparison techniques, the method of measuring the assessment dimensions will change.

3. As a result of the application of pairwise comparison, the reliability of the PRISM risk assessment process will increase, and the consistency of the experts' opinions could be examined.

4.2   The case studies and their findings

I used the case study methodology to examine the capabilities of the method development presented in my dissertation.

From the detailed description of the methodological development found in Chapter 4 of my dissertation, it can be seen that its application is independent of the nature of the risks examined and the field of operation of the organization applying the methodology, so when selecting the cases, I chose organizations whose operational characteristics can be used to draw sufficiently

generalizable experiences. When describing the case studies, I follow the relevant steps of the methods described in Chapter 4 of my dissertation step by step.

The first case study examines the risk management process applied at a commercial bank and compares its experiences with the results achieved by applying the PRISM methodology combined with the Guilford procedure. The majority of the risks examined focus on the financial area and the compliance of banking processes. The lower number of risks examined, as well as the fact that due to the examination of financial issues, two events characterized by the same numerical value rarely occur (almost excluded), so it is difficult to imagine two risks with the same qualification and consequence, justified the application of the PRISM method combined with the Guilford procedure.

The proposed risk assessment methodology is based on the aggregation of individual expert opinions, so the problem in the examined banking practice can be easily remedied and avoided with its help. In the applied banking practice, only 4 risk categories (insignificant, moderate, significant, critical) are defined and used, so in the case of several events to be assessed, several events will receive the same rating, thus the ability to distinguish their importance will be low. The application of the proposed, with the Guilford procedure combined PRISM method, is able to create a more finely detailed scale compared to the method used in banking practice (using a continuous scale instead of a scale containing 4-element discrete values), so a more accurate picture can be obtained with its help in relation to the assessment of individual non-compliance cases. Although only a few emerging problems were addressed in this case study, it was inspiring for the compliance experts of the bank in the case study (and also for the compliance experts of other commercial banks, who assess their risks in a similar way to the described practice) to continuously improve their banks' compliance management systems.

The second case study comes from the energy industry, examining the risks of the logistics department of a nuclear power plant. This problem area examines mainly technical issues, the exploration of which typically provides measurable results, and in the pairwise comparison of individual risks, it is possible that experts may judge the risk of individual events to be the same. This is why this case uses the AHP-TOPSIS-based extension of the PRISM methodology.

The aim of the case study was to demonstrate the functionality of the AHP-TOPSIS-based extension of the PRISM risk assessment methodology through a nuclear power plant risk assessment example. The methodology, based on the 3 risk assessment dimensions used in the application of FMEA, expands the basic PRISM methodology and helps to identify and present underestimated or hidden partial risks. The PRISM assessment process uses deterministic assessment scales, therefore the data sensitivity of the method is critical. Although combining the analytic hierarchy process (AHP) with the PRISM method helps to alleviate some of the disadvantages of the original methodology, the AHP-PRISM method is still unable to solve the problem of the equal factor weight of the assessment dimensions. This example demonstrates the application of a methodology (AHP-TOPSIS-PRISM) that allows for the use of different factor weights for evaluation dimensions and an in-depth analysis of each alternative by comparing it with positive and negative ideal solutions. Since the TOPSIS methodology can

provide an efficient solution in ranking compared to other methods, it was a suitable direction for expanding the AHP-PRISM methodology.

5   Results and theses of the research

This chapter summarizes the main findings of my dissertation, answers the research questions, and sets out my theses.

5.1   Research question #1, assumption #1, thesis #1

1. What additions are needed to the PRISM methodology, which would allow the comparability of risks as well as the reliability of the evaluators?

The PRISM methodology approaches the ranking of risks by comparing sub-risks, which would remain hidden, for example, during a traditional FMEA analysis. By presenting the relationships between sub-risks, it provides a visual tool for risk assessors. By default, the PRISM methodology does not provide an opportunity to exclude evaluator subjectivity (even unintenional ones), and it gives a distorted picture of risks in the case of different factor weights of the assessment dimensions. Based on examples from the literature, these problems can be remedied by integrating with other techniques, such as MCDM.

By analyzing the pairwise comparisons of experts performing risk assessments, their expert reliability can be evaluated and qualified, so that, if necessary, we can make a decision to accept or reject the results of their work. If the level of consistency of their assessment is not adequate, their opinion formation can be excluded from subsequent analyses.

By rating the work of the evaluators, experts with opinions that differ significantly from the common opinion of the evaluator group (outliers) can also be identified, in which case they can also be excluded from the study, which may even induce further studies to explore the background of their different opinions (the current level of development of the proposed methodologies does not yet provide an explanation or solution for this).

At the same time, the use of pairwise comparisons also modifies the applicability area of the PRISM method, making it applicable at a strategic level. As the number of pairs to be compared increases, the evaluator's work becomes more difficult, so it is more difficult for evaluators to achieve the reliability characterized by consistency that is expected of them.

1. assumption: If the PRISM method remains suitable for risk management even after integration with various pairwise comparison techniques, then the pairwise methodologies will also allow for the examination of expert consistency (with a lower number of cases).

1. thesis: As a result of the integration of the PRISM method with various pairwise comparison techniques, expert consistency can be examined. Due to the limited number of pairwise comparisons, the focus of risk assessment shifts from the operational level to the strategic level.

5.2 Research question #2, assumption #2, thesis #2

2. How can the expansion of the original PRISM methodology with certain MCDM techniques provide a methodological solution to decision/risk management problems arising in a given application area?

The AHP-TOPSIS-PRISM methodology performs comparisons with different factor weights. In this case, the visualization ability of the methodology deteriorates, but this is offset by the advantages provided in the ranking of risks. If the need for visualization is high when applying the methodology, the PRISM method combined with the Guilford method is recommended, since it still uses the same factor weights, thus the visualization ability of the PRISM methodology is not deteriorated.

Both the Guilford method and the AHP-TOPSIS-based extension allow the PRISM method to be compared based on pairwise comparisons of risks against the deterministic measurement scale of the PRISM method. This results in a more detailed comparison, since it compares risks with each other according to their relative importance (each element is compared with each element).

The increase in the number of pairwise comparisons changes the focus of the PRISM method: it becomes strategically focused instead of managing operational risks. The peculiarity of the method development is that the number of comparable elements becomes limited, so it is not advisable to use it for the evaluation of a large number of risks at the operational level.

As a result of the extension of the PRISM methodology with the Guilford procedure, decision-maker indifference is not allowed, therefore it is recommended to use it only in situations where the evaluators can clearly take a position on the preference of individual elements. In contrast, the AHP-TOPSIS-based extension allows for evaluator indifference, which does not narrow the range of risks that can be examined.

2. assumption: When combining the PRISM methodology with pairwise comparison techniques, the method of measuring the assessment dimensions will change.

2. **thesis**: By combining the PRISM methodology with pairwise comparison techniques, it is still possible to identify the relative importance of risks. The AHP-TOPSIS-based extension of the PRISM methodology allows the use of different factor weights for the evaluation dimensions, while the extension with the Guilford procedure preserves the visualization capabilities of the PRISM methodology while using the same factor weights.

5.3 Research question #3, assumption #3, thesis #3

3. How does the use of pairwise comparisons change the PRISM risk assessment process?

The evaluation process is modified towards the characteristics of the nominal group when using PRISM methodologies combined with pairwise comparisons compared to the original PRISM method. The use of pairwise comparisons provides the opportunity for individual evaluation and then for its consistency check, thus the negative effects of the group evaluation used by

PRISM (for example, the influence of the dominant opinion maker) can be reduced. The evaluators can give their evaluation in individual work, and then this can be summarized after the consistency check, thus group effects that can distort the evaluation can be prevented.

The use of consistency check allows the exclusion of the opinion formation of decision-makers with inadequate consistency from the evaluation, and the identification of different opinion formations that differ significantly from the common value judgment.

The PRISM methodology requires personal, simultaneous presence when preparing the evaluation. In the case of using methodologies extended with pairwise comparisons, simultaneous presence is not a prerequisite.

3. *Assumption: As a result of the application of pairwise comparison, the reliability of the PRISM risk assessment process will increase, and the consistency of the experts' opinions could be examined.*

3. **thesis**: As a result of the application of pairwise comparison:
   a) inconsistent evaluators can be excluded from the risk assessment process based on the consistency test,
   b) the assessments of individual experts become comparable in detail,
   c) the emphasis shifts to individual assessment processes, and opinions that differ significantly from the common opinion may induce further investigations into the assessment process.

6   Limitations, managerial applications

The common feature of the methodological developments presented in my dissertation is that it develops the PRISM method through integration with methods based on pairwise comparisons. Thus, the limitations of my work can be interpreted on the one hand in terms of the characteristics that can be considered as a given of the methods used, and I also address the limitations arising from the circumstances of application, for which I have also presented typical solutions in the literature related to these limitations. My aim is not to strive for completeness, but to briefly present some fundamental limitations and describe their impact on my work.

As I have already briefly presented in the methodological chapter, the technical apparatus of pairwise comparisons is extensive, of which I have used the methods that can be considered basic. One important limitation of the Guilford method regarding usability is that basically the decision-making expert must clearly choose between the two pairs (equality, i.e. identical classification is not allowed). This also means that when selecting the elements to be compared, it is important to pay attention not to include elements with very similar meanings in the analysis, because their comparison cannot be meaningful. This is especially true when the Guilford method is used in the assessment of the severity of the consequence.

For example, if we want to examine the risk situation of whether the right wing or the left wing of an airplane will have a more serious consequence in terms of keeping the airplane in the air, then it is clear that the Guilford procedure presents an insoluble problem, because the Guilford

procedure does not allow for indifference for the decision maker. This problem can be overcome by including the item in the "wing detachment" category in the comparison and not making a distinction between right and left wings.[1].

The above limitation of the PRISM methodology combined with the Guilford method is solved by the AHP method, since it allows indifference when comparing two elements. It is another matter whether indifference will still result in a measurable decrease in consistency, which would not be justified from the practical point of view. One important limitation of the development with the AHP is that the evaluation scale used by the AHP often leaves too much room for subjective approaches, which can cause distortion of expert assessments.

Although the extension of the AHP-TOPSIS method to the PRISM methodology provides a solution for handling the different weights of the evaluation dimensions, it causes a step back in the visualization of the representation of risks compared to the basic PRISM method.

The following table summarizes the essential characteristics of the pairwise comparison-based extensions of the PRISM method.

Method	Factor weights for evaluation	Measurement method	Decision-maker indifference	Visualization capability	Decision making level	Number of alternatives
PRISM	same	deterministic scale	allowed	significant	operational	high
Guilford-PRISM	same	pairwise comparison	not allowed	significant	strategic	limited
AHP-TOPSIS-PRISM	different	pairwise comparison	allowed	not significant	strategic	limited

When solving practical problems, it is worth taking the following considerations into account when making a managerial choice:

1. If the weights of the evaluation dimensions are the same and the evaluation is based on deterministic scales, then the basic PRISM method is recommended, which provides sufficient visual support during the evaluation.
2. If the weights of the evaluation dimensions are the same and the evaluation is based on pairwise comparisons, then the PRISM method extended with the Guilford procedure is recommended, which provides sufficient visual support during the evaluation.
3. If the weights of the evaluation dimensions are different and the evaluation is based on pairwise comparisons, then the AHP-TOPSIS-PRISM method is recommended, which, however, can only provide limited visual support during the evaluation.

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[1] The effect of the limitation is clearly visible when, in the example mentioned above, we want to compare the consequences of the tail and wing of an airplane being torn off.

References

Andrade, José.M.M., Leite, Athon., Canciglieri, Matheus B., Szejka, Anderson L., Loures, Eduardo., and Canciglieri Osiris. 2020. A Multi-Criteria Approach for FMEA in Product Development in Industry 4.0. *ADVANCES IN TRANSDISCIPLINARY ENGINEERING, 12, 311-320* https://doi.org/10.3233/ATDE200090

Ball, David J. and Watt, John. 2013. Further Thoughts on the Utility Risk Matrices. *Risk Analysis Vol. 33, No. 11, 2068-2078.* https://doi.org/10.1111/risa.12057

Banghart, Marc., Babski-Reeves, Kari., Bian, Linkan., and Strawderman, Lesley. 2018. Subjectivity in failure mode effects analysis (FMEA) severity classification within a reliability centered maintenance (RCM) context. *International Journal of Aviation, Aeronautics, and Aerospace*, 5(1), 2. https://doi.org/10.15394/ijaaa.2018.1191

Benedek, Petra., Bognár, Ferenc., and Kövesi, János. 2021. A rejtett kockázatok becslésének egy új lehetősége - A PRIZMA módszer alkalmazása compliance menedzsment érzékeny területen. in. *Szentes, Balázs (szerk.): A digitális transzformáció hatásai és kitörési lehetőségei a COVID utáni időszak karbantartásában – Nemzetközi konferencia kiadványa. Pannon Egyetem Gazdaságtudományi Kar, Veszprém (2021) pp. 81-92. , 12 p.* ISBN: 978-963-396-213-8

Bognár, Ferenc., Benedek Petra. 2022. A novel AHP-PRISM risk assessment method – An empirical case study in a nuclear power plant. *Sustainability* 14(17): 11023. https://doi.org/10.3390/su141711023

Bognár, Ferenc., Hegedűs Csaba. 2022. Description and Consequences on some Aggregation functions of PRISM (Partial Risk Map) Risk Assessment Method. Mathematics 10(5): 676. https://doi.org/10.3390/math10050676

Braglia, Marcello, Frosolini, Marco, and Montanari, Roberto. 2003. Fuzzy TOPSIS approach for failure mode, effects and criticality analysis. *Quality and Reliability Engineering International, 19(5), 425–443.* https://onlinelibrary.wiley.com/doi/10.1002/qre.528

Chakraborty, Subrata. and Yeh, Chung-Hsing. 2009, July. A simulation comparison of normalization procedures for TOPSIS. In 2009 *International conference on computers & industrial engineering* (pp. 1815-1820). IEEE. https://doi.org/10.1109/ICCIE.2009.5223811

Chakraborty, Subrata, and Anuradha, Mandal. 2018. A novel TOPSIS based consensus technique for multiattribute group decision making. In *2018 18th International Symposium on Communications and Information Technologies (ISCIT)* (pp. 322-326). IEEE. https://doi.org/10.1109/ISCIT.2018.8587952

Chakraborty, Subrata. 2022. TOPSIS and Modified TOPSIS: A comparative analysis. *Decision Analytics Journal, 2,* 100021. https://doi.org/10.1016/j.dajour.2021.100021

Cinelli, Marco., Kadziński, Miłosz., Miebs, Gregorz., Gonzalez, Michal., and Słowiński, Roman. 2022. Recommending multiple criteria decision analysis methods with a new taxonomy-based decision support system. *European Journal of Operational Research* 302(2): 633-651. https://doi.org/10.1016/j.ejor.2022.01.011

Cox, Louis Anthony (Tony) Jr.. 2008. What's wrong with Risk Matrices? *Risk Analisys Vol.28 No.2:497-512.* https://doi.org/10.1111/j.1539-6924.2008.01030.x

Deák, Csaba. 2005. FMEA. in. *Szintay, István (szerk.) Minőségmenedzsment II. Gyakorlat* (o. 71–80). Bíbor Kiadó. Miskolc. ISBN 963 963412 3

Doff, René. 2008. Defining and measuring business risk in an economic-capital framework. *Journal of Risk Finance* 9 (4): 317–333. https://doi.org/10.1108/15265940810894990

Duijm, Nijs Jan. 2015. Recommendations on the use and design of risk matrices. *Safety science, 76,* 21-31. https://doi.org/10.1016/j.ssci.2015.02.014

Elmontsri, Mustafa. 2014. Review of the strengths and weaknesses of risk matrices. *Journal of Risk Analysis and Crisis Response* Vol. 4, 49–57. https://doi.org/10.2991/jrarc.2014.4.1.6

Forgács, Anett, Lukács, Judit, and Horváth, Richárd. 2021. The Investigation of the Applicability of Fuzzy Rule-based Systems to Predict Economic Decision-Making. *Acta Polytechnica Hungarica* 18(11): 97-115. https://doi.org/10.12700/APH.18.11.2021.11.6

Guilford, J. P. 1928. The method of paired comparisons as a psychometric method. *Psychological Review, 35(6), pp. 494–506.* https://doi.org/10.1037/h0071114

Hanggraeni, Dewi., Ślusarczyk, Beata., Sulung, Liyu Adhi Kasari., and Subroto, Athor. 2019. The Impact of Internal, External and Enterprise Risk Management on the Performance of Micro, Small and Medium Enterprises *Sustainability* 11, no. 7: 2172. https://doi.org/10.3390/su11072172

Horváth, Zsolt., and Szlávik, Péter. 2011: Vállalati integrált kockázatkezelés I–II. *Minőség és Megbízhatóság,* 2011/3. szám pp. 124–130 és 2011/4. szám pp. 219–226.

Hwang, Ching-Lai, and Yoon, Kwangsun. 1981. *Multiple Attribute Decision Making: Methods and Applications. New York: Springer-Verlag* https://doi.org/10.1007/978-3-642-48318-9_3

Kosztyán, Zsolt Tibor., Csizmadia, Tibor., Hegedűs, Csaba., and Kovács, Zoltán. 2010. Treating measurement uncertainty in complete conformity control system. *in. Sobh, T. (eds) Innovations and Advances in Computer Sciences and Engineering. Springer, Dordrecht.* https://doi.org/10.1007/978-90-481-3658-2_14

Kovács, Zoltán., Csizmadia, Tibor., Mihálcz, István., and Kosztyán, Zsolt Tibor. 2022a. Multipurpose Aggregation in Risk Assessment. *Mathematics 10: 3166.* https://doi.org/10.3390/math10173166

Kovács, Zoltán., Csizmadia, Tibor., Mihálcz, István., and Kosztyán, Zsolt Tibor. 2022b. A vállalati kockázatkezelésben használt aggregálófüggvények jellemzése. *STATISZTIKAI SZEMLE, 100 (9). pp. 821-853.* https://doi.org/10.20311/stat2022.9.hu0821

Könyves, Melinda Katalin., and Kalló Noémi. 2022. A kockázatelemzés változásai: Az új FMEA megközelítés. *POLGÁRI SZEMLE, 18(1-3), 250–261.* https://polgariszemle.hu/10.24307/psz.2022.1118

Ni, Huihui., Chen, An., and Chen, Ning. 2010. Some extensions on risk matrix approach. Safety science, 48(10), 1269-1278. https://doi.org/10.1016/j.ssci.2010.04.005

Pellegrino, Roberta. 2025. Risk management of Circular Economy: a framework based on Interpretive structural model. *Procedia Computer Science*, *253*, 683-690. https://doi.org/10.1016/j.procs.2025.01.130

Pfohl, Hans-Christian, ed. 2002. *Risiko-und Chancenmanagement in der Supply Chain: proaktiv–ganzheitlich–nachhaltig.* Vol. 20. Erich Schmidt Verlag GmbH & Co KG, ISBN 3 503 06674 8

Rapcsák, Tamás. 2007. Többszempontú döntési problémák. MTA-SZTAKI

Redmill, Felix. 2002. Risk analysis-a subjective process. *Engineering Management Journal*, *12*(2), 91-96. https://doi.org/10.1049/em:20020206

Rezaei, Jafar. 2015. Best-worst multi-criteria decision-making method. *Omega 53: 49–57.* https://doi.org/10.1016/j.omega.2014.11.009

Saaty, T. L. 1980. The Analytic Hierarchy Process, New York: McGraw-Hill, ISBN:978-0070543713

Saaty, R. W. 1987: The analytic hierarchy process—what it is and how it is used. *Mathematical Modelling, 9(3-5), pp. 161–176.* https://doi.org/10.1016/0270-0255(87)90473-8

Sadgrove, Kit. 2016. The complete guide to business risk management. Routledge, 3rd ed., ISBN 978-1-4724-4219-2

Szakály, Dezső. 2005. Failure Mode and Effect Analysis: Hibamód és hatáselemzés FMEA. *in. Szintay István (szerk.) Minőségmenedzsment III. Alkalmazás (o. 107–131).* Bíbor Kiadó. Miskolc, ISBN 963 963413 1

Taherdoost, Hamed., and Madanchian, Mitra. 2023. Multi-criteria decision making (MCDM) methods and concepts. *Encyclopedia*, *3*(1), 77-87. https://doi.org/10.3390/encyclopedia3010006

Yazdani, Morteza., Gonzalez, Ernesto. D.R.S., and Chatterjee, Prasenjit. 2021. A multi-criteria decision-making framework for agriculture supply chain risk management under a circular economy context. *Management Decision*, *59*(8), 1801-1826 https://doi.org/10.1108/MD-10-2018-1088

List of own publications

Publications relevant to the topic of the dissertation:

Bognár, Ferenc., ***Szentes, Balázs***., and Benedek, Petra. 2022. Development of the PRISM risk assessment method based on a multiple AHP-TOPSIS approach. *Risks*, *10*(11), 213. https://doi.org/10.3390/risks10110213

Bognár, Ferenc., ***Szentes, Balázs***., and Benedek, Petra. 2023. Compliance Risk Assessment in the Banking Sector: Application of a Novel Pairwise Comparison-Based PRISM Method. *Complexity*, *2023*(1), 9165815. https://doi.org/10.1155/2023/9165815

Szentes, Balázs. 2024. Páros összehasonlítás alapú PRIZMA módszer. *In: Benedek, Petra (szerk.) Kockázat és megbízhatóság a gazdasági döntésekben: Konferenciakötet , Budapest, Magyarország: Wekerle Sándor Üzleti Főiskola 48 p. pp. 2-11. , 10 p.* https://m2.mtmt.hu/gui2/?mode=browse&params=publication;35643079

Szentes, Balázs. 2025a. Risk Assessment Based on Pairwise Comparison – a Potential Development for PRISM Method. in: *T. Kiss, Judit (szerk.) New Trends and Challenges in Management – Management of Global Business Processes".* Debrecen, Magyarország: Debreceni Egyetem (2025), 74 p. p. 43 ISBN: 9789634907268 konferenciaelőadás https://m2.mtmt.hu/gui2/?mode=browse&params=publication;36211650

Szentes, Balázs. 2025b. Kockázatok kezelése páros összehasonlításon alapuló módszerekkel. *in: Nyeste, Zsolt; Szentes, Balázs (szerk.) A KARBANTARTÁS STRATÉGIAI SZEREPE – BIZTOS VÁLASZOK KELLENEK BIZONYTALAN IDŐKBEN.* Veszprém, Magyarország : Magyar Ipari Karbantartók Szervezete (2025) pp. 107-115. , 9 p. ISBN: 9786150234014 https://m2.mtmt.hu/gui2/?mode=browse&params=publication;36109967

Szentes, Balázs. 2025c. Kockázatértékelés páros összehasonlítással – Egy módszerfejlesztés tapasztalatai. *In: Benedek, Petra (szerk.) Minőségmenedzsment és értékteremtés* Budapest, Wekerle Sándor Nemzetközi Egyetem, pp. 16-32., 17 p. https://m2.mtmt.hu/gui2/?mode=browse&params=publication;36312758

Szentes, Balázs. 2025d. A PRIZMA módszertan páros összehasonlítással történő integrációja. *In: Benedek, Petra (szerk.) Dealing with Uncertainty and Managing Risk (megjelenés alatt)* https://m2.mtmt.hu/gui2/?mode=browse&params=publication;36312761

Szentes, Balázs., and Bognár, Ferenc. 2024. Kockázatértékelés páros összehasonlítási alapokon – Kihívások és lehetőségek. *in. I. Gaál Zoltán Konferencia, 2024. november28-29., Veszprém, absztraktkötet*, ISBN:978-963-396-288-6

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