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A novel Approach to Risk Management for University Research Projects

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Abstract: Large-scale infrastructure projects are often characterized by a high degree of innovation but are also accompanied by uncertainties and risks. In university research projects, the complexity is even higher because, in addition to unknown factors, like unclear paths forward, they come with adaptive targets.

These lead to higher uncertainties, and it is crucial to adhere to the magic triangle of project management to continuously monitor and ensure the achievement of the project goals. Additionally, in research, a dead-end does not inevitably lead to the failure of the project, but mostly it leads to new opportunities. This paper explores the relationship between project goals and risk management of university projects to create a tailored project plan. First, the challenges and needs were mapped out through a survey of ten project leaders at our university. This survey helped us understand the problems and led to a new approach for university projects. Second, the new approach including adjusted risk management and methodology is developed. Third, the results were combined with a project plan using a probabilistic methodology to modify the approach through predictive evaluations. This includes integrated cost, time, and risk analysis. The probabilistic results are based on a Monte Carlo simulation. In the paper differences and similarities between the management of large-scale infrastructure projects and research projects are highlighted.
Therefore, a process for creating an exemplary, holistic project plan using a digital twin, which helps to optimize the management strategy for research is presented. Furthermore, the project plan is tailored to the needs of applied research, so that the results of the research can be useful for the industry.

Keywords: risk management, research projects, goals, infrastructure projects

1. INTRODUCTION

Construction projects are often considered highly risky due to their complexity and duration [1, p. 2]. Many large infrastructure projects therefore exceed both the budget and the determined schedule [2]. Planning and decision-making are often characterized by conflicts of interest due to the involvement of many stakeholders [3]. In university research projects they also struggle with budget and time overruns due to their inherent complexity [4]. Therefore, this paper examines how adapted risk management supports the development of a project plan to make project control more effective for research. The problems and challenges are identified through interviews with ten project leaders at the University of the Bundeswehr in Munich. A possible approach is derived and included in a probabilistic holistic project plan. Furthermore, differences and similarities between infrastructure projects and research projects are examined.

2. DIFFERENCES AND SIMILARITIES BETWEEN LARGE-SCALE INFRASTRUCTURE PROJECTS AND UNIVERSITY RESEARCH PROJECTS AT THE MANAGEMENT LEVEL

2.1. Legal and contractual framework conditions

In public large-scale infrastructure projects, there are naturally many laws and regulations in addition to the client specifications, guiding the process and conditions for conducting the project, for example, on how a road or a tunnel should be constructed. In university research projects, however, these must comply with the respective budget regulations, possibly the guidelines of the funding, and the respective university and innovation law. In contrast, specifications are usually formulated very abstractly. For example, the third-party funding guidelines for the Bundeswehr University in Munich only stipulate that the contact details of the project leader, short project description, expected project duration, the amount of the specified third-party funds, and possible follow-up costs must be recorded [5]. This can be referred to in Germany by Article 5 of the German Constitution: "Freedom for Art and Science, Research and Teaching". Nevertheless, it is essential in university research to adhere to the time and budget plan, which is controlled by the management or applicant.

Another difference between construction projects and university research projects lies in the intended financial volume. Third-party income at German universities totaled around €9.5 billion [6], while €444 billion was spent in the construction sector in Germany in 2021 [7]. Nevertheless, both types of projects can be described as risky and complex due to their novelty. Therefore, effective project management is required to ensure successful outcomes.

2.2. Uncertainty and risks in the development process

The uniqueness and high degree of innovation of the research project make it difficult to formulate concrete goals and define milestones in advance. Research projects have more unknown factors to overcome than large construction projects, leading to an increase in project complexity. Therefore, it is important to integrate adaptive risk management into university research to minimize risks and at the same time make project control more effective. In general, the task of risk management is to identify, analyze, evaluate, and monitor the opportunities and threats of a project, thereby increasing the chances of project success [8]. In university research projects, hypotheses are usually formulated as the research motive, which is either rejected or confirmed by intensive processing of the research question. Even the rejected hypothesis leads to new knowledge gain and is considered a project success. These changes make it difficult to assess the changes in the final budget and time planning, making project control difficult. To address these challenges, university research projects were examined more closely.

3. INTERVIEWS

3.1. Motivation for conducting the interviews

To identify the approach and improvement potentials for project management, interviews were conducted with ten project leaders at the University of the Bundeswehr in Munich. These were randomly selected to avoid biasing the sample. Only project leaders were interviewed, as this is one of the prescribed positions in university research projects. Therefore, they are primarily responsible for management. The explorative expert interview method was used to collect facts and information to develop research objects [9]. The condition at the time of the interview was examined [10, p. 11]. To combine the benefits of standardized and unstandardized interviews, a mix of both types was conducted. Therefore, a discussion guide was developed, which was also sent to the participants in advance. The guide consisted of predefined multiple-choice questions and free-text fields allowing the participant to provide additional information. The conducted interviews lasted between 45-75 minutes. For the development of applicable models, the subjective opinion of the participants is important, which is why the chosen interview format has proven to be particularly suitable [11]. The focus lies on the results of the project objectives and the methodological use of risk management. The following sections will discuss the interview results relevant to the work in the areas of prior knowledge, complexity, project objectives, risk management, and their methodical use.

3.2. Prior knowledge and complexity

At first, the project leaders were asked about their professional experience. 50 % stated that they had gained professional experience in both industry and academia. Since all the project leaders surveyed are professors, their highest educational qualification is a doctorate. 80 % of the participants have more than 20 years of professional experience. 20 % of the respondents were between 10-20 years. 80 % of the respondents were male and 20 % female. The professional affiliation was widely varied from psychology, natural sciences, mathematics, media, communication, and marketing to engineering and technology, as well as computer science, health, and medicine. To learn more about the composition of the projects, the project leaders were asked about cooperation partners, the number of persons involved, and the budget allocated. Here, complexity could be identified in all projects based on Windolph [12].

3.3. Project objectives

The participants were questioned on the objectives of the research projects. For a more detailed assessment of the answers, a point scheme with a scale of 1-5 was chosen (1 = does not apply; 2 = largely does not apply, 3 = applies partly, 4 = largely applies, 5 = applies fully). Due to the ten project leaders, a maximum of 50 points were possible. The results can be seen in Figure 1.

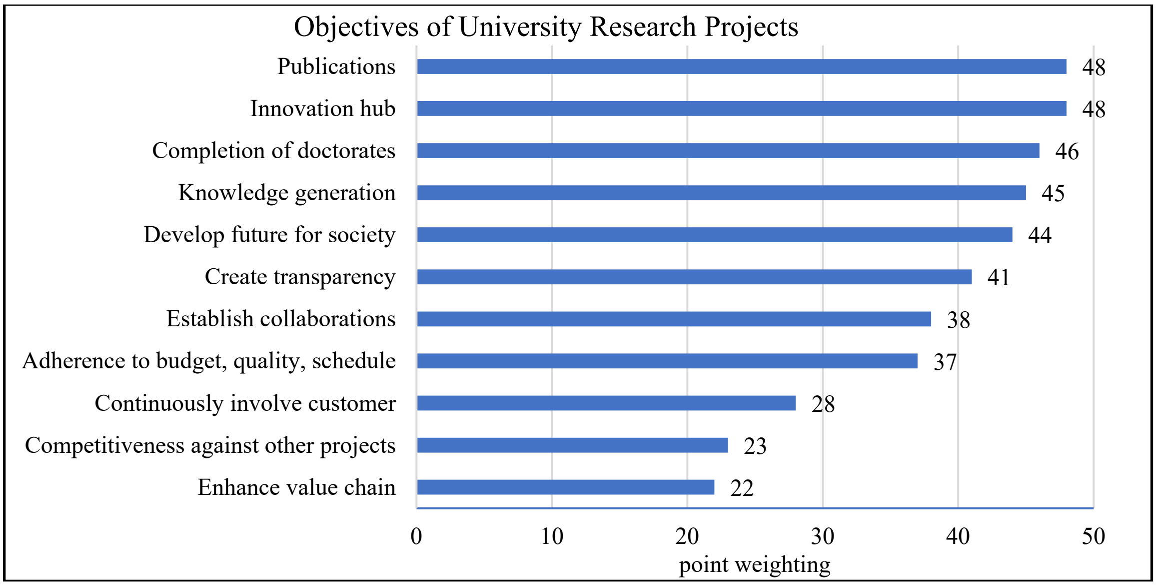


Figure 1. Objectives of University Research Projects

With 48 out of a possible 50 points, both the degree of innovation and publications were considered the most important objectives. It was also very important to complete doctoral degrees and generate knowledge. This reflects that scientific activity is at the forefront. Adhering to project framework goals (budget, quality, and time) ranked somewhat lower with 37 points. This means that project management does not primarily contribute to subjective goal achievement. Even if, as estimated by the German Research Foundation (Deutsche Forschungsgemeinschaft), time and budget must be adhered to. This can lead to goal conflicts or goal exclusion. In addition to the points listed, one person also considered it important to increase the university's reputation.

The scientific focus in university projects is also reflected in the information that only four of the ten projects surveyed had employed a project manager in addition to the project leader. Reasoning in, that they suffered from resource scarcity, did not see management as their task, or entrusted scientific staff with this task in addition. It was not important to them to compete with other projects or that the value chain gets improved.

3.4. Risk management and methodical use

In Figure 2, the currently used project management methods can be seen. This was also differentiated into the individual phases of risk management. This was divided into Risk Identification (RI), Risk Analysis (RA), Risk control and Mitigation (RM), Monitoring and Communication (MC), and All Phases (AP). Multiple answers on methods and additional methods were listed. One person reported not using any methods. The methods that were not used are not listed further.

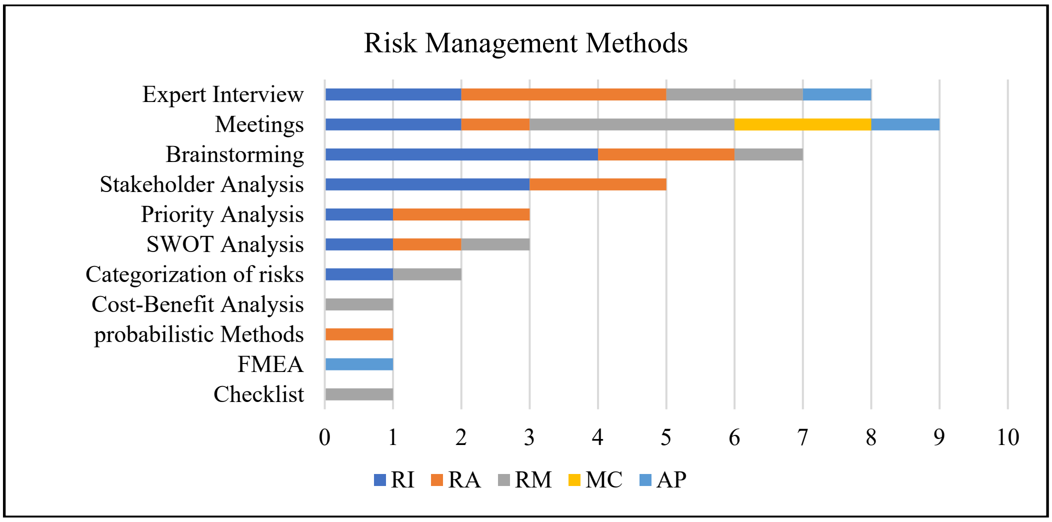


Figure 2. Risk management methods in university research projects

Collection methods are predominantly used, with analytical and creative methods being seldom applied. Comparing this with Romeike's assessment of the use of risk management methods, it is noted that most of the methods being utilized do not align with the respective project phases [13].

Furthermore, it was observed that project leaders who employ a project manager utilize more methods than those without. Some project leaders indicated that the current risk management practices do not meet scientific requirements. The reasons for using specific methods are similar to those for hiring a project manager: proven methods, scarcity of resources, lack of directives from management, directives from cooperation partners, or the perception that certain risks are uncontrollable and the methods are easy to apply. This reflects the trend of utilizing known and proven methods without adapting the risk management process. Additionally, most methods are used by project leaders with a project manager, highlighting resource allocation and effort. It was also investigated why the participants did not resort to other methods. This is mainly due to resource scarcity, lack of knowledge, and estimated time investment. Some stated that they do not see added value in using other methods. To assess the application of risk management methods by project leaders, they were surveyed on a scale of 1-5, similar to goal objectives. The six most important criteria for the application of risk management methods are: Ease of use, low time investment, communication enhancement, low documentation effort, structured approach, and quick adaptation to changed requirements. Project leaders value ease of use due to resource scarcity and prior knowledge.

3.5. Interpretation of the results and novel approach to risk management

The conducted study has shown that the project plan needs to be adapted to the needs of university research and thus the achievement of innovative goals. The following challenges were identified about project objectives, risk management, and method usage:

- Lack of expertise in project management
- Personnel scarcity
- Only familiar methods are used
- Priority of scientific objectives
- Risk management not tailored to research
- Methodical approach initially not considered
- Scientists do not want to be managed

The use of methods has revealed that flexibility in requirement definition and defined structure is desired. To methodically and reliably estimate uncertainties and risks, methods that can make forecasts for the future and support an adaptive approach are suitable. Additionally, risks should be able to be aggregated to transparently represent complex interactions. Making forecasts is also an important factor for innovative construction projects to be able to react quickly to changes in scope. Furthermore, future scenarios help to depict reality and provide a better estimation of budget and time schedules, which is especially important for long project and construction durations.

The evaluation also revealed that most scientists, like university project leaders, pursue scientific objectives and assign less importance to management objectives. This can lead to a conflict of interests. To avoid this, scientists and relevant research questions should also be continuously involved in the project. This is also extremely relevant for large-scale infrastructure projects to continuously inform all internal project participants as well as stakeholders and involve them from the beginning [14]. Moreover, this also considers the conflict of interests, by the Principle-Agency-Theory, which is relevant, among other things, for contract conclusion in construction projects. Continuous collaboration with management can also promote understanding of processes and their course, which in turn has a positive impact on cooperation and acceptance of project management.

In university research projects, it is particularly important to achieve innovation goals as well as to promote publications. The uncertainty of the results poses a risk to the success of the project, but also to its completion. However, they can also be an opportunity to achieve an even better result. In research, gaining insights can also be considered a success, as they are not dependent on turnover and bonuses as in construction projects.

For uncertain processes, research hypotheses should be integrated as a central element for integrating risk management into project planning and, consequently, into the project plan. The aim is to avoid goal deviations and conflicts of interest and to create innovations. This is also an important goal for complex construction projects to avoid competitive struggles in fulfilling contracts.

4. ESTABLISHING THE PROBABILISTIC HOLISTIC PROJECT PLAN

The chapters above have demonstrated that goals must be defined first. At the start of the project, the project manager or project leader needs to define scientific questions as typical goals set by the project management triangle. Due to the recognized uncertainty in method usage, a workshop in addition to the methodical approach would be advisable.

For goal setting, relevant research questions for the project are to be established. Goals are loosely formulated for the project manager but in collaboration with the scientific personnel or stakeholders. Similar to construction projects, all stakeholders should be involved in the process to minimize conflicts of interest. These research questions must have both a theoretical and practical basis to be usable for applied research or industry. The subsequent approach is based on the Lean startup method, which is used to reduce uncertainties in start-ups, that is, new business ideas, and to transform ideas into successful products [15]. This is utilized for hypothesis formation and theoretical and practical applicability. The method is supported by the Plan-Do-Check-Act cycle (PDCA), which is regarded in the field of quality management [16].

The PDCA cycle is used to make the hypotheses verifiable through a feedback loop in a short time and to support goal achievement. Since the research only has often just a generic target group, the defined target group must be incorporated into the hypotheses for practical applicability and value. Subsequently, these are to be broken down into multiple hypotheses (top-down) and provided with interim goals. Each interim goal must be verifiable. The interim goals should be SMART (specific, measurable, achievable, reasonable, time-bound) formulated and represent scenarios for the rejection and acceptance of the hypotheses (Step 1 - Plan).

Mapping hypotheses-related risks using interim goals enables better control and reduces uncertainties. For hypothesis-related risks, opportunities, and threats with probabilities of occurrence and severity levels are defined for acceptance and rejection. The severity level is provided in terms of days and/or costs to analyze the impact on project management goals (time, cost, quality). For risk identification, additional methods can be used to depict future scenarios. For example, the Delphi method can be used as it is often employed in research contexts (Step 2 – Do) [17, p. 14].

After testing the hypotheses, it is evaluated whether the hypothesis and its associated risks are confirmed or rejected. This gets compared with the goals, and strategies developed if necessary to minimize risks (Step 3 - Check).

In the final step, it is examined whether adjustments to the objectives are necessary and what insights have been generated. This, in turn, may require adjustments to the project plan. Additionally, a feedback loop is established to incorporate improvements (Step 4 - Act). The procedure can be seen in Figure 3.

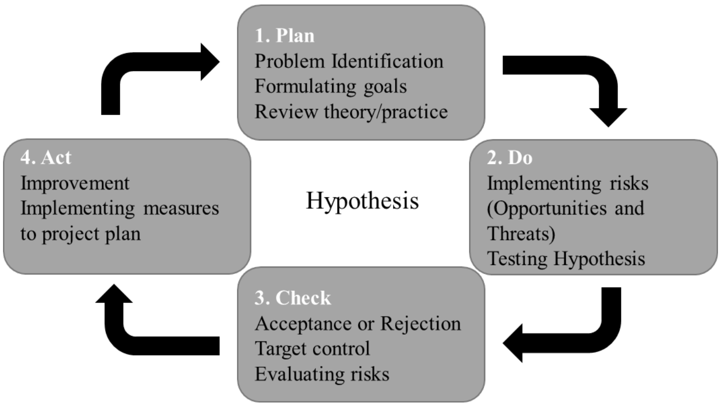


Figure 3. Formulating hypothesis for uncertain processes

The now-known data is entered into the RIAAT software as an example. This program is currently used for large, complex infrastructure projects such as tunnels, bridges, or airports. The program has already been successfully tested to detect time delays and budget overruns for construction projects [18]. Additionally, RIAAT combines cost management, scheduling, and risk analysis in a fully transparent project [19]. This approach is very helpful to include all groups of interest. A possible procedure for the implementation of research projects will be shown.

The input for the program to create a Project Risk Twin consists of cost estimation, budget planning, initial scheduling, and identified risks. The hypothesis-related risks and other identified risks are then entered into the program, resulting in a *Risk Register*. For inputting the risks, a bandwidth range planning approach including distribution functions is chosen to make forecasts more meaningful and reduce uncertainties by providing higher information content [20, 21]. The costs are incorporated using a *Work Breakdown Structure (WBS)* and provided with uncertainties and distribution functions for a three-point estimate (best, most likely, and worst case). This can, for example, include costs from contracts, procurements, as well as inflation costs. The currently relevant risks from the risk register are linked to the WBS. An excerpt from the program can be seen in Figure 4.

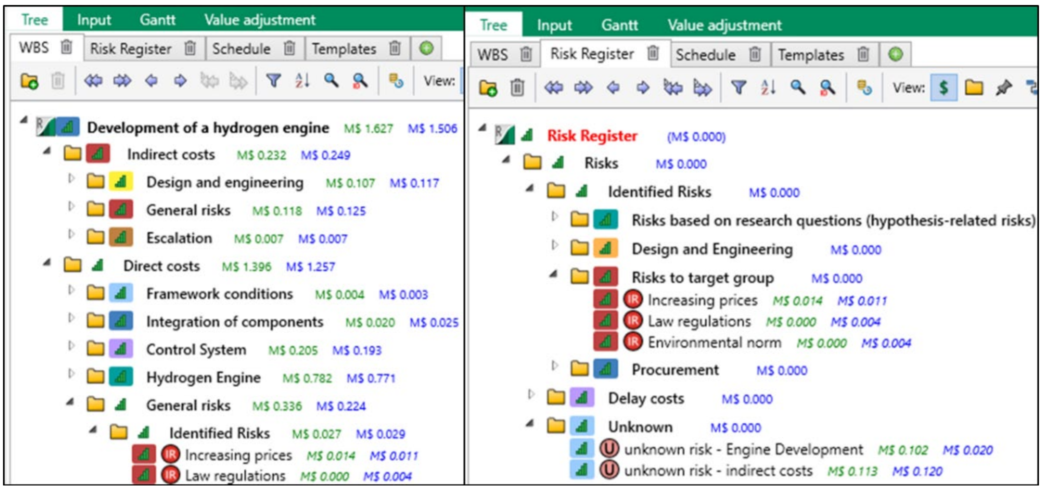
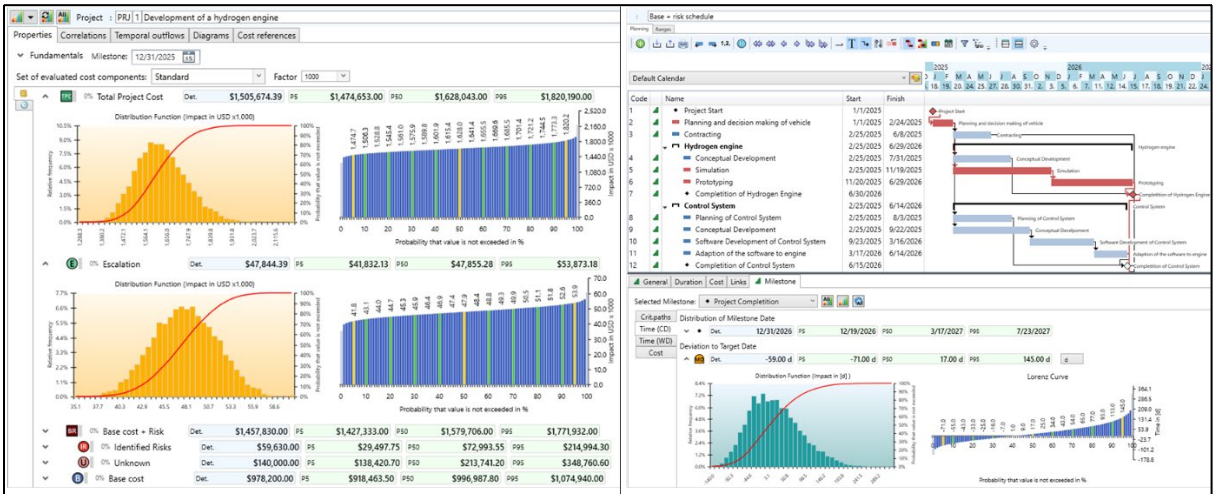


Figure 4. WBS and risk register

Then, the schedule and milestones are established in coordination with the interim goals of the hypotheses. Goals and milestones are roughly defined at this stage. Additionally, a target date is set for when the milestone should be achieved. This serves as goal control, as the target date is compared with the actual completion date for forecast determination. The risks and time-related costs can now be linked with the schedule. This allows an aggregated representation to demonstrate the impacts, for example, caused by project or construction time extensions resulting in additional costs (personnel). This is also important for infrastructure projects to detect construction time extensions and budget overruns early. A Monte Carlo simulation is used to calculate the various scenarios.

For the output, the uncertainties and risks for the schedule (target date vs. completion date) and planned budget vs. actual costs are checked for conformity. This enables the generation of dashboards, indicating the extent to which goals are still achievable or need to be adjusted. Furthermore, it is possible to generate the critical path to further control (marked red on the schedule in Figure 5). *Probabilistic results for cost and time*, for example, in the form of histograms, are provided. Furthermore, the close hypothesis formulation and verification help sustainably meet goals and improve quality management. Figure 5 shows an exemplary excerpt.



Probabilistic results for cost components | Integrated schedule with risks and milestone analysis

Figure 5. Exemplary model in RIAAT

5. CONCLUSION

Integrating comprehensive risk management in all complex projects is essential to respond to rapid changes in requirements and paradoxical outcomes. The developed approach aims to validate project objectives over time and, through efficient method application, enhance project control. The current risk management framework will continue to be tested and continuously improved. However, the methodical approach offers an advantage for project control by involving researchers, stakeholders, and project managers in risk management through continuous communication and flexible goal adjustment. While risks cannot be completely eliminated, they can be controlled through appropriate methods. This helps to respond quickly to hypothesis-related risks and sustainably adhere to time and budget constraints. Furthermore, it supports meeting innovative goals, which are also relevant for creating the future.

In future steps, the model will be evaluated regarding the correct definition and application of hypotheses and objectives. Therefore, project management is crucial to meet the specific needs of a university research project and address the challenges identified in the interview. This methodical approach to include the hypothesis-related risks based on research questions can also be useful in infrastructure projects when it comes to uncertain processes and/or involved research institutions. Through meticulous hypothesis formulation, goals can be evaluated, and risks arising from the innovative process can be minimized.

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