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RESEARCH ARTICLE
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Green Energy Project Management: Applying Industry-Specific Risk Assessment Models

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ABSTRACT

By reducing reliance on fossil fuels, green energy projects mitigate climate change by lowering carbon dioxide and other greenhouse gas emissions. They push governments and society to transition to renewable energy production by implementing high-risk green energy projects more effectively. This study evaluates how risk management processes affect the efficiency of green projects in Kazakhstan, identifying critical risk management processes that can increase their success. The methodology is based on data collected from 66 experts in Kazakhstan's green energy sector. Using multilinear regression analysis, the Project Management Body of Knowledge (PMBOK) standard was applied to evaluate the relationship between risk management processes and project efficiency dimensions. The findings show a positive correlation between cost overrun and project performance with the implementation of risk management processes. The statistical significance levels underscore the importance of these findings. The lack of statistical significance for schedule overrun, combined with the low rate of qualitative risk analysis and monitoring among local managers, highlights a deficiency in proactive risk management, leaving projects vulnerable to adverse impacts. These findings impact project management professionals and organizations involved in sustainable energy initiatives, providing valuable insights to enhance their risk management processes. This study paves the way for future research by adding more respondents and using other risk analysis methods, opening new avenues for improving risk management in green energy projects.

KEYWORDS: Economics and Business, Project Management, Risk Management, Green Energy Projects, Project Efficiency, PMBoK, Kazakhstan.

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1. INTRODUCTION

In the dynamic landscape of project management, the ability to identify, assess, and mitigate risks is crucial for ensuring the successful and timely completion of projects. Effective risk management becomes a priority as organizations increasingly engage in complex and multifaced green energy projects. Moreover, industry-specific risk analysis tools can help organizations tailor their risk management strategies to the unique challenges they face and discover best practices for mitigating risks that are specific to a particular industry (Carro et al., 2021). It's important to note that each industry has its own unique risks that need to be thoroughly analyzed and appropriately addressed in order to ensure the safety and efficiency of the processes.

Moreover, industry-related risks can not only hinder the success of the project but also block its potential progress and prosperity (Chebotareva et al., 2020). For instance, missed opportunities in cost reduction (planning and resource allocation) or innovation (lack of best practices on the market) could result. Thus, relevant risk management could give a business a competitive advantage. It can help one differentiate themselves or their organization by demonstrating a strong understanding of industry-specific challenges and solutions.

The risk assessment in the green energy industry differs significantly from other industries because it belongs to high-tech projects characterized by high risk and uncertainty levels and complex technologies. Unlike low-tech sectors, green energy projects involve assessing risks associated with resource variability, such as weather-dependent energy sources, or navigating evolving technologies and incorporating them to ensure their effectiveness (Choo&Go, 2022). It is also essential to consider risks considered in managing market volatility influenced by policy shifts and global events (Deng et al., 2014). The distinctive characteristics of green energy projects demand a specialized risk perspective to ensure effective risk mitigation and project sustainability. Therefore, this study aims to evaluate how risk management can affect the efficiency of green energy projects in the Republic of Kazakhstan.

By examining the existing risk assessment models, project managers in the green energy sector can gain a comprehensive understanding of the existing frameworks available to them. This overview will serve as a foundation for the subsequent sections, which will delve deeper into the application, challenges, and adaptations of risk analysis models in the context of the green energy sector.

Thus, the risk management processes from the PMBOK standard were used in terms of their ability to contribute to overall project success, specifically regarding budget and schedule overruns, as well as the project team's satisfaction with the project. The study identifies the critical risk management processes for project efficiency that can be used by project managers who run green energy projects.

The rest of the paper is designed as follows: Section 2 comprises a comprehensive literature review, thoroughly exploring prior research and the concept of risk assessment. Section 3 outlines the methodology for evaluating risks and introducing the techniques utilized in the process. Section 4 delves into the research outcomes and discoveries. Finally, Section 5 concludes the study with a summary of the research findings, identification of limitations, and suggestions for future research directions.

2. LITERATURE REVIEW

The green energy industry has unique challenges that stem from its dependence on rapidly evolving technologies, regulation, and the interconnectedness of global environmental issues. Unlike traditional low-tech industries, the green energy sector is often at the forefront of innovation, making it an ideal case study for the application of advanced risk analysis models. However, due to its distinctive characteristics and newly emerged manner, the green energy sector also needs more extensive research in risk assessment. For example, it's identified that there are so many defects in the traditional ways of risk assessment when it comes to renewable energy investments and management (Escande et al., 2016). The authors have identified many uncertainties and suggested that studies on this topic can help investors and managers manage risk and reduce losses, which also benefits the development of the renewable energy industry.

Kozhakhmetova et al. (2019) compared the efficiency dimensions of green energy projects with those from other industries, including IT, communication, and nanotechnology. They identified cost overrun, schedule overrun, and project performance as key metrics. Nanotechnology projects showed the worst results, exceeding planned costs by 91.9% and schedules by 6.6%. The researchers attributed this underperformance to project complexity, risk exposure, and the infrequent use of project management. This highlights the importance of project and risk management in all high-tech projects, including green energy. Similarly, green energy projects showed a schedule overrun of 6.2% and a low-performance level of 7.5%. These findings indicate that green energy projects are not as efficient as expected, necessitating improvement efforts.

Several risk assessment models, such as Failure Modes and Effects Analysis (FMEA), Hazard and Operability (HAZOP), and Environmental Impact Assessment (EIA), are commonly used in project management for the green energy sector. These models help identify, analyze, and manage risks associated with complex projects like renewable energy and energy storage.

Figure 1 shows a basic form of FMEA that identifies essential information to reduce or eliminate a root cause from a design and a process.

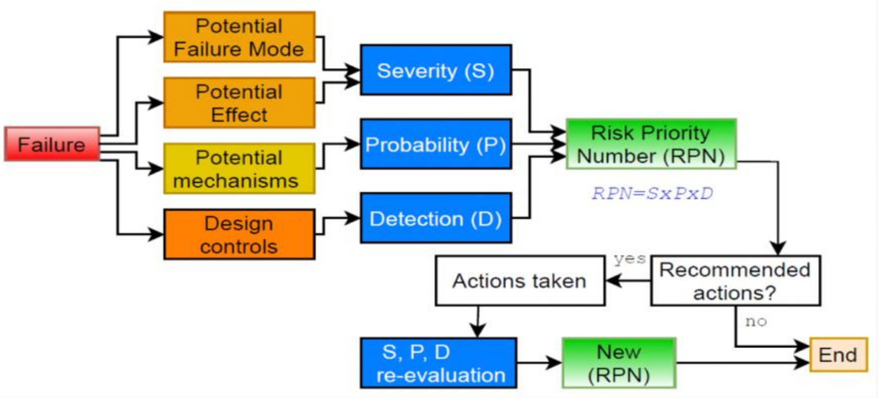

FIGURE 1. Typical FMEA pathway

Note: compiled by authors

FMEA and studies are mentioned in almost all literacy Foussard and Denis-Remis Hyett (2010) FMEA is a technique that "evaluates designs hazard and operability (HAZOP) and identifies potential failures and their probability of occurring". This type of analysis is fundamental for safe design, operation, and potential scaling up, all of which can be and are applied in the energy sector and widely used across all industries. The FMEA aims to eliminate potential failures or reduce their impacts. This analysis is built around three elements: the effect, the cause, and the detection. Figure 2 shows the initial list of items and the overall PRM process captured in the PMBOK Guide.

FIGURE 2. The PMBOK PRM process

Note: compiled by authors

The following tool that is widely used in risk assessment is HAZOP. Interestingly, a new version of HAZOP has been developed in the sustainable development sector: Green HAZOP or g-HAZOP. It initially emerged to recognize potential risks when working with highly harmful materials and abolish everything that can probably lead to a severe accident, such as explosions, fires, toxic releases, etc. Later, its use was expanded to other kinds of services due to its capability to recognize hazards and identify functional deviations from the preferred state (Li et al., 2021). Choo and have identified the HAZOP method as the most popular probabilistic-based risk assessment tool for energy and storage systems, which makes it highly relevant to this project of green energy (Liu&Zheng, 2017). Another widely used risk assessment model is EIA. The main purpose of the EIA is to assess the possible impacts of an activity or a document on the environment and develop proposals for the prevention or minimization of negative effects (Marhavilas et al., 2020). The risk assessment part (ERA) of the EIA offers a more holistic assessment and enables the integration of environmental, social, and economic aspects. It also assists in prioritizing issues requiring management (Bennett, 2005).

In Figure 3 there is shown extended PRM process.

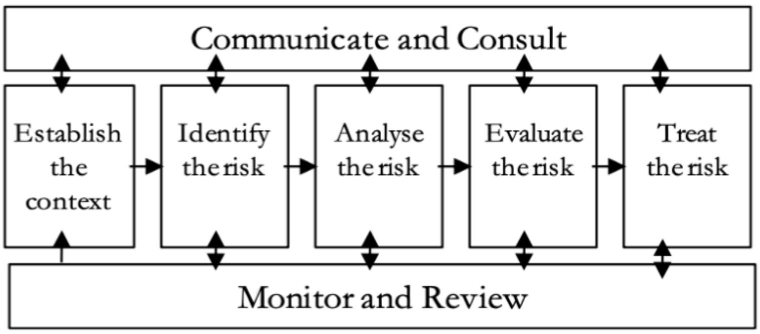

FIGURE 3. The extended PRM process

Note: compiled by the authors

Last but not least, the PRM (Project Risk Management) technique provides guidance concerning project development to ensure better resource management within the most common constraints (e.g., time, cost, and quality). Large organizations generally use published models, such as the CMMI (Capability Maturity Model Integration) or PMBOK, the latter being the most well-known PM "best practices" reference (Mutlu & Altuntas, 2019).

The PMBOK PRM process from Figure 3 can be extended to incorporate two categories: "management support tasks" and "communication and inclusion practices" that encompass all PRM steps and were identified in the literature (Pegels et al., 2018; Pillay & Wang, 2003; Pritchard, 2001).

Despite being largely used, the above methods have also been longingly criticized (Pubule et al., 2012). All methods and tools have limitations, and the limitations of FMEA, HAZOP, and EIA will be studiedEven though FMEA is one of the most robust and widely used risk analysis methods, it has shortcomings. Those limitations in the decision-making processes include a need for more consideration of human factors and accuracy in determining risk priority number (RPN) (Robichaud, 2005; Roseke, 2018). The quality of the HAZOP analysis heavily relies on the knowledge and experience of the team conducting it. If the team lacks expertise or diversity, critical hazards may be overlooked. Moreover, as in FMEA's case, it has inaccuracy in weighting: it considers equivalent weights for the risk factors. It means that "low-probability and high-consequence" and "high-probability and low-consequence" hazards are approximately equivalent.

Overall, Escande's study of the current risk assessment methodology's limitations suggests that a root cause of the risks must be identified to identify the factors affecting project success (Shankar & Prabhu, 2001). Escande suggested closely investigating how risk analysis methods are implemented in real-time settings (observing the working teams) to understand better the conditions under which these methods are being used. Moreover, benchmarking has to be conducted by learning from past accidents. Lastly, a good fix could be adding another method to an existing one, as has been discussed earlier with FMEA and PMPQ. While HAZOP and FMEA are valuable for hazard analysis and failure mode assessment, they may provide a different level of coverage and adaptability to the risks and challenges faced in the green energy sector (Santos & Cabral, 2008). Generally, the literature review section compared existing risk management models like HAZOP, FMEA, PRM, and EIA and found PRM to be the most appropriate for green energy projects. This model is advantageous for green energy project management compared to HAZOP and FMEA. The model provides a more comprehensive risk assessment framework than HAZOP or FMEA, as it covers many risks relevant to green energy projects. Thus, the literature review helps to choose PRM as the most suitable for assessing the relationship between risk management processes and project green energy projects' success metrics. Moreover, specific project success dimensions such as project performance, cost, and schedule overrun were identified.

3. METHODOLOGY

Research design

This research aims to evaluate the Project Risk Management (herein PRM) model under PMBOK standard in terms of its ability to contribute to overall project success, specifically regarding budget and schedule overruns and the project team's satisfaction with the project. The model involves three main processes:

(1) Risk identification and Evaluation (Planning stage);

(2) Risk handling (Executing stage);

(3) Risk controlling (Monitoring stage).

The PRM model entails a total of six processes, which are further categorized within the three processes mentioned earlier. The research model is depicted in Figure 4 below.

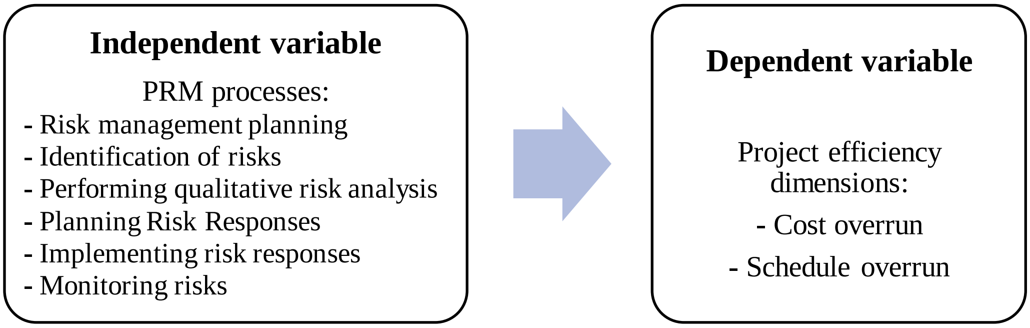

FIGURE 4. Research design

Note: compiled by authors

As shown in figure 4, this study, with its meticulous approach, will specifically focus on assessing the effectiveness of these six processes in managing the risks associated with projects in the green energy field. The success of the project's performance will be measured through key indicators such as cost overrun, schedule overrun, and the achievement of project goals.

Data collection

The survey was used as a data collection method as it allows to effectively gather necessary information for the research question in this paper. This data collection approach provided an unbiased basis for the examination of the results of this research. The online software called Google Data Forms was used for the conduction of the survey as it allowed for anonymous and fast data collection process. The participants answered 11 questions in relation to their project. Moreover, 100% of the questions were answered by the respondents.

Research sample

In Figure 5 there is provided data on the experience of respondents

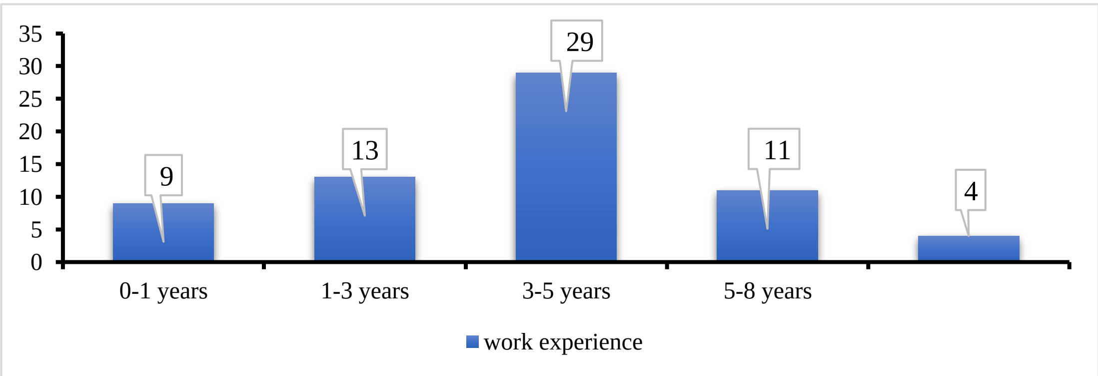

FIGURE 5. The work experience of the respondents

Note: compiled by authors

The survey was conducted among 66 participants that were either managers or leaders of the projects in the green energy sector. In order to identify projects in the green energy sector which could be enlisted in this research, the governmental companies such as

"Baiterek Holding", CGE as well as "Samruk Green Energy" were used as they entail lists of green energy projects completed. The detailed description of the respondents' work experience is shown in Figure 5 below. This figure provides a snapshot of the distribution of work experience levels within the respondents, highlighting the varying levels of professional experience among surveyed project managers and supervisors. As shown in Figure 5, 44% have 3-5 years' experience in PM, while the most experienced respondents are 4 out of 66.

Data processing

The results were analyzed using multilinear regression analysis in Excel. The respondents were asked about the intensity of the six risk management processes used when executing green energy projects. They ranked it on a Likert scale from 1 to 5. Project success is evaluated by schedule and cost overruns, which are measured in percentages, and project performance is assessed by a Likert scale from 1 to 10.

4. RESULTS AND DISCUSSION

The analysis section provides the results of examining the PRM model within the projects in the green energy sector. Table 1 shows the overall analysis of the data collected in this study in the green energy field.

TABLE 1. Data summary of the analysis in the green energy field

Measurement	P-value	R	Interpretation
Cost overrun	<0.001	0.41	Existing correlation, high significance
Schedule overrun	>0.05	0.15	Low correlation, low significance
Project Performance	<0.001	0.57	Existing correlation, high significance

Note: compiled by authors

As can be seen from Table 1, the results for Cost overrun and Project performance have been calculated to correlate with the implementation of Project Risk Management processes and high statistical significance levels. For instance, Cost overrun (R=0.41) and project performance (0.57) have a statistically significant positive correlation with risk management processes, meaning that project budgeting and performance improvements are associated with proper risk management tactics. The results in Figure 6 describe the average percentages of cost overrun and schedule overrun for selected projects.

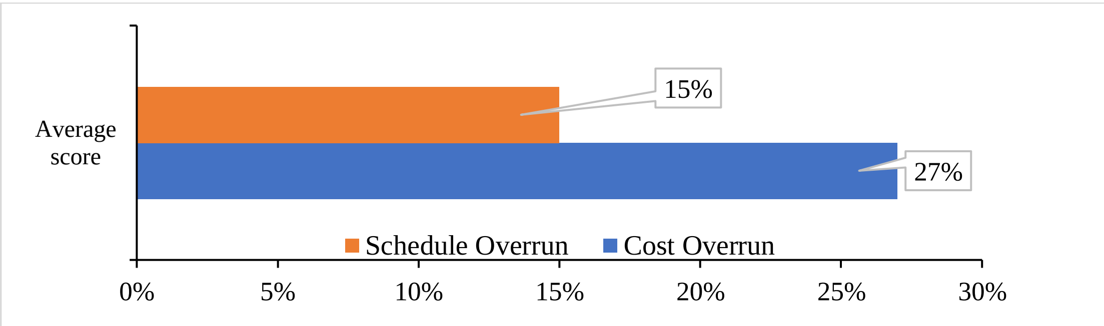

FIGURE 6. The average scores for Cost Overrun and Schedule Overrun

Note: compiled by authors

As shown in Figure 6, Cost Overrun indicates that, on average, the projects or tasks are experiencing a cost increase beyond their initially estimated budget. Specifically, projects are running, on average, 27% over budget in terms of costs. The score of Schedule

Overrun (15%) suggests that the projects or tasks are taking longer to complete than initially planned or scheduled. Projects are, on average, delayed by 15% beyond their original timelines. These metrics help to assess how well projects are adhering to their planned budgets and schedules. High percentages in either category can indicate inefficiencies or unexpected challenges in project execution.

The statistics results for the Cost overrun, Schedule overrun measurement and Project performance are presented below in Table 2.

TABLE 2. Detailed description of the Cost overrun indicators, Schedule overrun, Project performance

Dimension	N	Multiple R	Coefficient	F significance
Cost overrun	66	0.4	-25.13	0.00063
Schedule overrun	66	0.2	-1.86	0.22
Project performance	66	0.57	1.32	4.67156E-07

Note: compiled by authors

The table shows that the coefficient for PRM for Cost Overrun is -25.13, which means that as PRM increases, the Cost overrun decreases. As projects carry out the PRM processes, they decrease the likelihood of overspending the project budget. Moreover, the significance level of the F-test for the regression model shows a very low p-value equal to 0.000637, which means that the results are statistically significant. The analysis shows that the coefficient for PRM for Schedule. Overrun is -1.86, which means that the intensive use of risk management processes decreases the Schedule overrun. Moreover, the P-value for the PRM is at a significance level of 0.22, which means that the results are not very statistically significant. It can be seen from Table 4 that the coefficient for PRM for Project performance is 1.32, which means that the active use of risk management processes positively impacts the reaching of the goals and aims of the project. Moreover, it can be seen that the P-value for the PRM is at the level of significance of 0.0000000467, which means that the results are statistically significant. The average of the 7 project risk management processes for each project was calculated, and its relation to each of the three measurements of the project's success has been calculated.

Table 3 illustrates the exact project risk management processes that were analyzed in this study.

TABLE 3. Project Risk Management processes

Project Risk Management Process	Average indicator across projects
Risk management planning	4.72
Identification of risks	3.90
Performing qualitative risk analysis	2.51
Planning Risk Responses	4.15
Implementing risk responses	2.66
Monitoring risks	2.59
Evaluation of cost and budget	4.04

Note: compiled by authors

It can be seen from Table 3 that the risk management planning process, on average, was performed on a higher level at 4.72 out of 5. Meanwhile, the qualitative risk analysis and monitoring were performed on an average lower level across 66 projects examined in this study. Thus, the study assumes that more attention should be paid to risk monitoring and qualitative risk analysis. This may be due to the low level of project managers' experience and qualifications in using monitoring and analytical tools.

Table 4 outlines the critical PRM processes for efficiency dimensions.

TABLE 4. Identifying the critical PRM processes for efficiency dimensions

No.	Project Risk Management Process	Cost Overrun	Schedule Overrun	Project performance
1	Risk management planning	+	+	
2	Identification of risks	+		+
3	Performing qualitative risk analysis			+
4	Planning Risk Responses			
5	Implementing risk responses			+
6	Monitoring risks	+	+	
7	Evaluation of cost and budget	+		+

Note: compiled by authors

The results with a p-value equal to or lower than 0.05 and 0.001 were chosen as necessary. Risk management planning, risk identification, risk Monitoring, and cost and budget evaluation are critical processes for cost overruns, while schedule overruns are impacted by only risk management planning and monitoring risks.

Four PRM processes listed in Table 4 also impact project performance. These findings mean that derived processes may directly increase the appropriate dimensions of project efficiency. Therefore, project managers should focus on them when running their projects because each of these processes has its own tools and techniques. The results show that using proper risk management processes can decrease the cost overrun by supporting the planned budget. In addition, managers may perform projects better if they use project risk management processes from the PMBoK standard.

5. CONCLUSION

The study aimed to evaluate the relationship between risk management processes and project success dimensions in the Republic of Kazakhstan's green energy field. A comparative assessment of existing risk analysis models identified PRM within the framework of PMBOK as the most suitable methodology. According to the results of this research, performing risk analysis processes statistically significantly increases the likelihood of achieving the project's goals and reduces the chances of going over the budget. Also, it can be said that performing PRM results in the elimination of cost overrun issues and an increase in the chances of project goal achievement; however, meeting the deadlines – those results cannot be accounted for by the general population. Therefore, project managers running green energy projects should look for additional measures to decrease the schedule overrun. It's suggested that the schedule management knowledge area be performed based on the PMBoK standard, which focuses on managing the project schedules. Moreover, the low rate of qualitative risk analysis and monitoring processes revealed that these essential risk management activities are not conducted frequently or effectively within a green energy project. The study suggests using risk management software for purposes like Risk Cloud, Vendor 360, and Project Risk Manager, which can help monitor and perform a risk analysis. The study has several limitations connected with sample size, methods used, and the quantity of variables.

The research covers only 66 respondents due to the small size of the green energy market in the Republic of Kazakhstan and, accordingly, the supervisors who run such projects. Therefore, future research may expand this study by increasing the number of respondents from other industries. Further research may also use other risk analysis models and choose an additional list of variables.

AUTHOR CONTRIBUTION

Writing – original draft: Assel Kozhakhmetova, Aizhan Anarkhan.
Conceptualization: Assel Kozhakhmetova, Aizhan Anarkhan.
Formal analysis and investigation: Assel Kozhakhmetova, Aizhan Anarkhan.
Funding acquisition and research administration: Assel Kozhakhmetova.
Development of research methodology: Assel Kozhakhmetova Assel Kozhakhmetova, Aizhan Anarkhan.
Resources: Aizhan Anarkhan.
Software and supervisions: Aizhan Anarkhan.
Data collection, analysis and interpretation: Aizhan Anarkhan.
Visualization: Assel Kozhakhmetova, Aizhan Anarkhan.
Writing review and editing research: Assel Kozhakhmetova, Aizhan Anarkhan.

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