EXAMINING THE CRITICAL SUCCESS FACTORS FOR THE EFFICIENCY OF GREEN ENERGY PROJECTS

Kozhakhmetova A.K., Zhidebekkyzy A., Anarkhan A.K., Štreimikienė D.*

Abstract: In recent times, there has been a remarkable exponential interest in green energy projects, driven by their potential to significantly decrease greenhouse gas (GHG) emissions and reduce reliance on fossil fuels. However, such high-tech projects' complexity, expensiveness, and high uncertainty level necessitate new ways of increasing efficiency. Therefore, this study, with its clear aim to evaluate the efficiency of green energy projects and identify the critical success factors that can enhance efficiency, remains a compelling and relevant research endeavour. The study employed a rigorous methodology, using multilinear regression analysis to survey 123 project managers from Kazakhstan. This allowed for a comprehensive comparison of the efficiency level of green energy projects and low-tech projects. Research results show that green energy projects exhibit the highest percentage of schedule overrun at 23.9% and cost overrun at 32.7%, indicating substantial delays in project completion and extra expenses in budget compared with low-tech projects. Moreover, green energy projects show the least favourable results (7.3) regarding technological performance. The study reveals the following critical success processes enhancing project efficiency: project planning, scope and cost management, communication, and team management. Based on the processes of the Project Management Body of Knowledge (PMBoK) Guide, an algorithm for managing green energy projects was developed. This tool equips project managers with a process-based map, enabling them to run their projects effectively and enhance their efficiency.

Key words: project management, green energy project, high-tech project, renewable energy, project efficiency

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Introduction

* **Assel Kozhakhmetova**, PhD, Kazakh British Technical University, Kazakhstan;
✉ email: a.kozhakhmetova@kbtu.kz,
ORCID: 0000-0002-3077-2023
Aknur Zhidebekkyzy, PhD, Associate Professor, Al-Farabi Kazakh National University, Kazakh British Technical University, Kazakhstan;
✉ email: Aknur.zh@gmail.com,
ORCID: 0000-0003-3543-547X
Aizhan Anarkhan, PhD candidate, Al-Farabi Kazakh National University, Kazakhstan;
✉ email: aizhan2790@gmail.com,
ORCID: 0009-0008-9014-3385
Dalia Štreimikienė, prof., Széchenyi Istvàn University Győr, Hungary;
✉ corresponding author: dalia.streimikiene@gmail.com,
ORCID: 0000-0002-3247-9912

The world faces energy and climate crises that threaten the survival of the human species across the globe (Totten, 2008). Electricity consumption in both developed and developing countries is increasing sharply at 1% and 5% per year (Stambouli and Koinuma, 2012), being the cause of the production of thousand million metric tons of carbon dioxide (Goh et al., 2014). Consequently, it is anticipated that by the century's end, global temperatures will rise by 3–6 degrees Celsius (Agudelo et al., 2013). As a result, numerous nations have adopted renewable energy sources as an alternative electricity generation system to mitigate carbon dioxide's effects on global climate change (Goh et al., 2014; Ojaghlou and Uğurlu, 2023). They understand the need to develop new technologies and innovations to access clean, green, and cheap electricity (Akhmat and Zaman, 2013) and view the energy sector's transition to low carbon with increased use of renewable energy sources as a crucial objective (Štreimikienė, 2024). It has brought significant shifts in the renewable energy landscape in the past ten years (Renewables, 2023). In response to these pressing concerns, the world has witnessed an unprecedented rise in green energy projects, with an investment of over USD 300 billion in 2022 alone (Liao, 2023).

However, the implementation of green projects is not without its challenges. Firstly, these projects, typically identified as high-tech, are distinguished by their technological complexity, significant costs, intensive knowledge requirements, and high risk, differentiating them from other projects (Kozhakhmetova et al., 2019). This distinct combination of features requires the application of specialized project management tools and techniques that are different from those employed in low-tech projects (Sabden et al., 2020; Narbaev et al., 2022). Secondly, the failure rate of high-tech projects is alarmingly high, ranging from 90% to 99% (Sharma, 2008). This statistic underscores the low success and efficiency levels of green projects. Despite Kazakhstan's significant potential in developing green energy sources, it is too early to talk about the maturity of green projects because about 80% of the country's thermal and electrical energy is generated from coal and its derivatives (Sitenko et al., 2023). Given these challenges, the study aims to assess the efficiency of green projects compared to low-tech projects and to pinpoint the essential project management (PM) processes crucial for the success of green energy projects in Kazakhstan. To accomplish these objectives and address the challenges, the following research questions have been formulated:

RQ 1: Which PM processes are critical for green project efficiency dimensions in Kazakhstan?

RQ 2: Do PM styles differ in green energy projects and low-tech projects?

RQ 3: Is the efficiency of green energy projects less than low-tech projects in Kazakhstan?

The next sections of the study address the literature analysis, methodology of green project efficiency and critical factors assessment, research findings, and conclusion to answer these research questions.

Literature Review

The growing focus on green energy initiatives has emerged in line with the goals set out in the United Nations Sustainable Development Goals (SDGs), particularly SDG 7, aiming for accessible and environmentally friendly energy, and SDG 13, which promotes action against climate change. In recent years, this interest began to grow exponentially (Twidell, 2021; Huseynli, 2023; Mishchuk et al., 2023) because green energy projects can drastically reduce GHG emissions, particularly CO2 emissions

(Liao, 2023; Mukhtarov et al., 2023; Streimikiene, 2022). These projects could benefit GDP in developing economies due to the broader range of opportunities for implementation and technology leapfrogging (Zhao, 2023). Moreover, renewable energy projects have begun to be considered to reduce the economy's dependence on traditional energy sources, such as oil, gas, and coal, which currently prevail (Karatayev et al., 2016). By generating energy from renewable sources such as wind, solar and geothermal energy, hydropower, and biomass, these projects aim to mitigate greenhouse gas (GHG) emissions and lessen the dependency on fossil fuels (He et al., 2023).

However, the successful execution of green energy projects requires adherence to well-structured and internationally accepted project management practices. This is due to their inherent complexity, increased risk, unpredictable outcomes, and knowledge intensity (Sitenko et al., 2023). The study assumes that project managers executing these projects focus more on risk management knowledge. Therefore, the study proposed the first hypothesis, which assumes that green energy projects have better results in performing risk management processes than low-tech projects. Furthermore, the unique attributes of high-tech projects necessitate the utilization of project management methodologies and tools that differ from those employed in low-tech projects (Zwikael and Huemann, 2023). This finding leads to the second hypothesis: that green energy projects run using different PM processes than low-tech projects.

Project performance reflects the degree to which project outputs and outcomes meet budgetary objectives, timelines, and operational and technical standards (Ali et al., 2018). It should be noted that there is no standardised approach for evaluating the efficiency of a project, regardless of whether it is high-tech or low-tech. Project efficiency is typically defined as adhering to time and budget constraints. In contrast, effectiveness refers to the degree to which project specifications and customer needs are either met or solved (Jugdev and Muller, 2005).

Within project management discourse, the 'Iron triangle' stands out as a prevalent and regularly employed gauge of project efficiency. This concept encompasses cost, time, and quality, which clients and project stakeholders recognise as pivotal factors (Maqsoom et al., 2020).

Due to the specific characteristics of the renewable energy industry, green energy projects have some efficiency metrics. One of them is green financing. It is a practical policy in developing countries to reduce the risk of investing in green projects and increase efficiency by increasing the rate of return of green energy projects (Taghizadeh-Hesary and Yoshino, 2019). Green support is most significant in green finance sub-dimensions.

Cost-benefit analysis (CBA) is one method of evaluating project efficiency. It evaluates the financial viability of green energy projects by comparing costs and benefits over time. It considers factors such as initial investment, operating costs, energy production, and social and environmental benefits. CBA is widely used for decision-making but cannot adequately capture all externalities (Mankiw, 2014).

Environmental Impact Assessment (EIA) is a regulatory process that evaluates a project's environmental impacts before approval. It assesses potential impacts on ecosystems, air and water quality, and human health. EIA ensures compliance with environmental regulations but cannot conduct in-depth economic feasibility assessments (Wathern, 2019).

Zwikael and Globerson (2006) consider project efficiency and effectiveness as parts of project success. Efficiency, evaluated through factors like time and cost overruns, constitutes one aspect, while effectiveness, encompassing project performance and customer satisfaction, forms the other. The following figure outlines their interpretation of project efficiency (Figure 1).

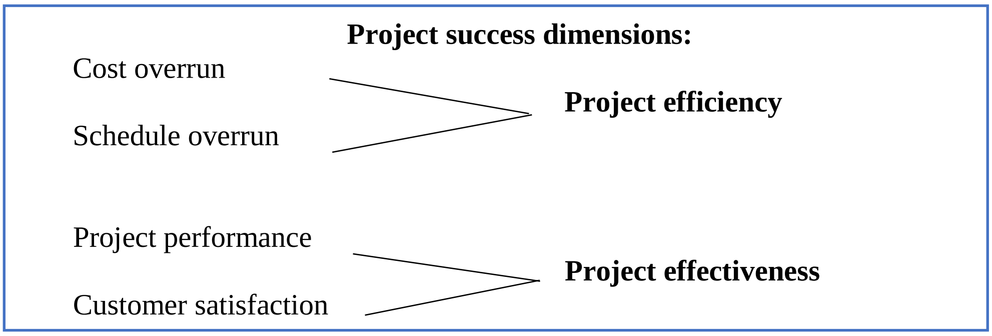

Figure 1: Zwikael and Globerson's criteria for project efficiency and effectiveness
Source: Zwikael and Globerson, 2006

Despite their significance, the terms efficiency and effectiveness are frequently used ambiguously within project management literature and need clear definitions. The authors mention cost overrun and schedule overrun as significant dimensions of project efficiency.

Further, the following table presents the most cited dimensions of project efficiency in the PM literature.

Table 1. Literature review summary on project efficiency dimensions

№	Project efficiency dimensions	Authors	Number of citations
1	Cost	Barbosa et al., 2021; Younus and Younis, 2021; Zhu et al., 2021; Rankin et al., 2008; Ling et al., 2009; Swarup et al., 2011; Wegelius-Lehtonen, 2001; Kabirifar and Mojtahedi, 2019; Sekar et al., 2018; Adamtey, 2019; Narbaev et al., 2024; Jugdev and Muller, 2012; Samoliuk et al., 2023.	13
2	Time/ Schedule	Chen and Lin, 2018; Barbosa et al., 2021; Zhu et al., 2021; Rankin et al., 2008; Ling et al., 2009; Swarup et al., 2011; Wegelius-Lehtonen, 2001; Kabirifar	11

№	Project efficiency dimensions	Authors	Number of citations
		and Mojtahedi, 2019; Sekar et al., 2018; Adamtey, 2019; Jugdev and Muller, 2005.	
3	Technical Performance/ Quality	Chen and Lin, 2018; Barbosa et al., 2021; Rankin et al., 2008; Swarup et al., 2011; Kabirifar and Mojtahedi, 2019; Sekar et al., 2018; Adamtey, 2019; Głodziński 2019.	8
4	Scope	Zhu et al., 2021; Swarup et al., 2011; Głodziński, 2019; Szatmari et al., 2021; Mossalam, 2020;	5
5	Customer satisfaction	Ling et al., 2009; Unterhitzenberger and Bryde, 2018; Wang et al., 2021; Ottaviani et al., *2024*.	4
6	Effective communication	Szatmari et al., 2021; Maqsoom et al., 2020; Zhu et al., 2021; Zwikael et al., 2023.	4
7	Safety	Sekar et al., 2018; Swarup et al., 2011; Mossalam, 2020.	3
8	Green support	Taghizadeh-Hesary and Yoshino, 2019; Kalmakova et al., 2021; Bhattarai et al., 2023.	3
9	Organizational support	Sabden et al., 2020; Zhidebekkyzy et al., 2019; Zwikael and Smyrk, 2011.	3
10	Artificial intelligence	Gladden et al., 2022; Narbaev et al., 2024; Roshchyk et al., 2022.	3

Table 1 offers a summary of the various aspects of project efficiency explored by different researchers, detailing the level of attention each aspect has garnered as indicated by citation counts. The dimensions most frequently cited include cost, schedule, and quality, which are assessed based on the technical performance of the project.

As revealed in the literature, one of the newest and least used tools for assessing the effectiveness of projects is artificial intelligence (AI). Krichevskiy and Martynova (2024) use this technology in a hybrid neuro-fuzzy system and formulate a quantitative assessment of the effectiveness of investment projects. The assessment was carried out by a neuro-fuzzy inference system like ANFIS (adaptive neuro-fuzzy inference system) using the MatLab R2012b software package. The limitation of this method relies on the requirement of technological skills from the user of AI and the complexity of data processing.

Overall, despite a wide range of works in the field of renewable energy, there needs to be more research on evaluating the efficiency of green energy projects. Projects in this field may fail due to a lack of experience, qualified human resources, the complexity of such projects, and the unmatured PM skills of local managers in Kazakhstan (Zhidebekkyzy et al., 2019). In addition, this type of project belongs to high-tech projects that involve substantial risk and high probability of failure (Shenhar, 2007). Green energy projects usually showcase state-of-the-art technology, which is a reason for the high uncertainty level (Szabó and Cserháti, 2013), and they often face cost overrun comparing low-tech projects (Shenhar, 2001). Therefore, the study suggests the third hypothesis: stating that green energy projects' efficiency level is lower than those of low-tech projects from other industries.

Thus, the literature review helps to choose the efficiency dimensions for further calculations and build the research hypothesis.

Research Methodology

The study consists of several steps to answer the research questions and check the hypothesis (figure 2).

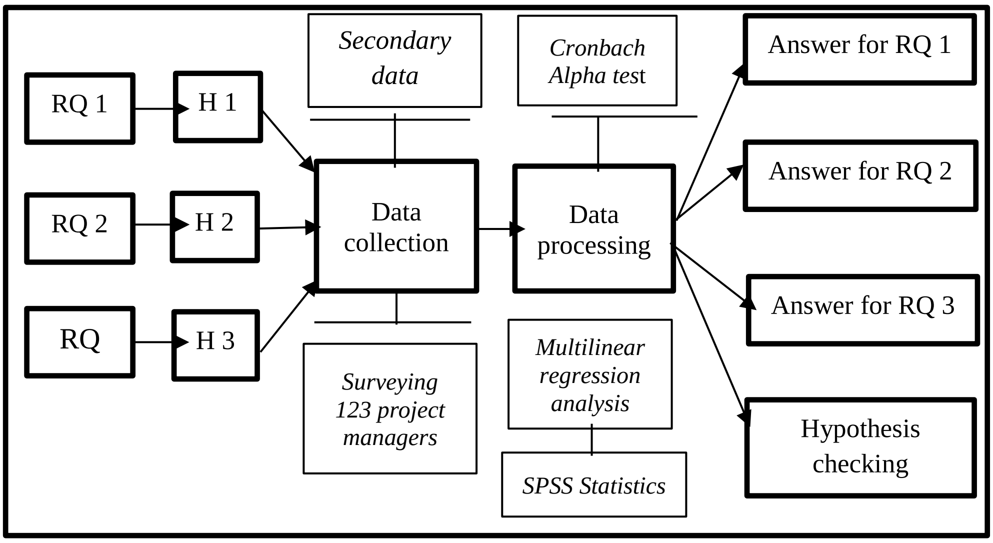

Figure 2: Research configuration

The research consists of several steps directed to primary and secondary data collection, quantitative data processing, checking the reliability and validity of the data, and summarizing the study through the discussion and conclusion of research findings. The research design containing the study's variables is presented below (Figure 3).

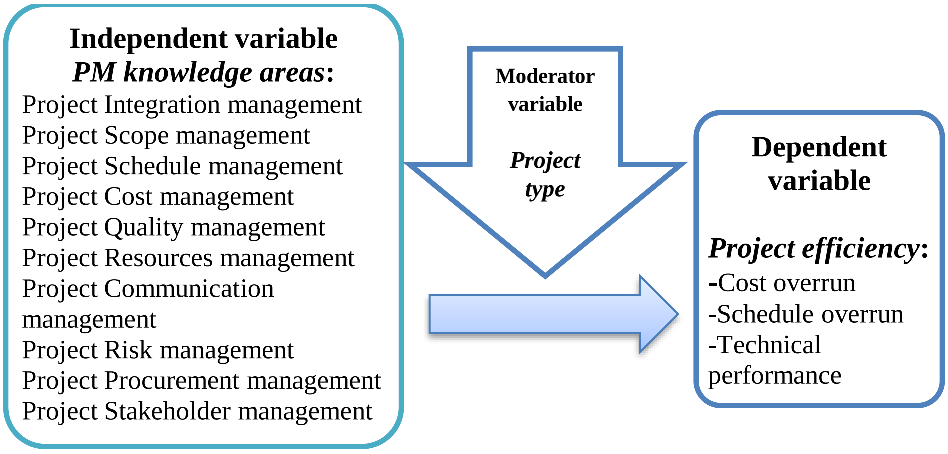

Figure 3. Research model

As Figure 3 shows, the research model is based on the PMPQ model designed by Zwikael et al. (2005). Independent variables are processes from 10 PMBoK guide knowledge areas, while dependent variables are project efficiency dimensions from the literature review. This research design helps to assess and compare the efficiency level of green energy and low-tech projects and identify critical PM processes enhancing the efficiency of green energy projects. Due to their technical characteristics, construction and scientific projects were chosen as low-tech for the research.

Research sample

The survey was conducted among supervisors and project managers implementing renewable energy projects in Kazakhstan. The original survey designed by Zwikael et al. (2005) was modified and translated into Russian and Kazakh languages—the total number of valid questionnaires was 123 out of 131. Data about green projects were collected only from the databases of the following official organizations: Wind Energy Development Fund, Baiterek Holding, Samruk-Green Energy, National Center for Renewable Energy, and International Center of Green Technologies and Investment Projects. These organizations invest in about 20-30 projects per year, so only a limited number of green energy projects were covered. Respondents were asked about the intensity of PM processes used in 10 knowledge areas. Each process is rated on a Likert scale from 1 to 5, with higher scores indicating better performance or effectiveness in that particular process. Then, they asked about project efficiency dimensions where schedule overrun and cost overrun were measured by percentage. A higher percentage indicates the low efficiency of the project. The next dimension, technical performance, was rated by a Likert scale from 1 to 10, where a higher score shows the highest results. The description of the research sample is depicted in the following figure (Figure 4).

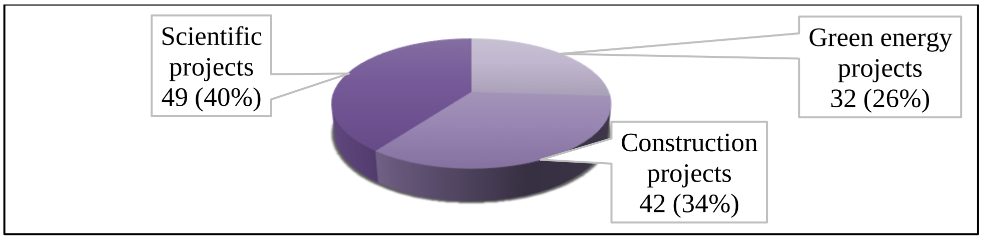

Figure 4: The research sample

The research sample contains 32 green energy projects, 42 construction projects, and 49 scientific projects.

Reliability testing

Using the SPSS program, the study conducted reliability testing to assess the significance of the distributed test questionnaire among companies and professionals in the logistics sector.

Table 2. Cronbach's Alpha test results

Variables slated for testing	Cronbach's Alpha score	Quantity of parameters	Interpretation
PM processes	0.79	10	Good reliability
Efficiency dimensions	0.81	3	Excellent reliability

As shown in Table 2, the Cronbach's Alpha score for PM processes was 0.79, indicating good reliability across ten parameters. In contrast, efficiency dimensions demonstrated an even higher Cronbach's Alpha score of 0.81, indicating excellent reliability across three parameters. These results show a high reliability and validity of the research results.

Research Results and Discussion

PM performance assessment

Table 3 presents data on the performance of various project management processes across three projects.

Table 3. Comparative use intensity of PM processes

	PM process	Green energy projects (n=32)	Construction projects (n=42)	Scientific projects (n=49)
1	Project plan development	***4.6***	***4.7***	***4.3***
2	Scope definition	2.2	*3.7*	4.0
3	Schedule development	3.3	**4.6**	**4.4**

4	Cost Estimating	3.7	**4.7**	4.1
5	Quality planning	**4.5**	4.4	*2.9*
6	Project team management	**4.0**	4.5	**4.4**
7	Communication planning	2.9	*4.2*	*2.9*
8	Risk management planning	*2.5*	*4.0*	*2.7*
9	Procurement planning	*2.7*	**4.6**	**4.5**
10	Stakeholder planning	3.5	4.4	*2.8*
	Average score	3.4	4.5	3.8

Note: bold font – the highest score, italic font – the lowest score

As seen from Table 3, construction projects perform consistently well across most project management processes (average score – 4.5), followed by Scientific projects (average score – 3.8). Green energy projects show the worst results, with an average score equal to 3.4. For Green energy projects, the top three processes based on their average ratings are Project Plan Development (average score – 4.6), Quality Planning (average score – 4.5), and project Team Management (average score – 4.0). It may be explained that green energy projects excel in developing comprehensive plans. Given the complexity and significance of green energy initiatives, meticulous planning is crucial, and the high rating in this process reflects a strong capability in this area. High-quality planning scores can be explained by quality requirements and standards applicable to green energy projects due to their high-tech nature. In addition, project managers focused on quality standards when dealing with complex green technologies.

The high rating for project team management suggests that green energy projects invest in building capable and cohesive project teams, providing them with the necessary support, resources, and leadership to perform optimally. Effective team management is crucial considering the interdisciplinary nature of green energy projects, which typically require collaboration among engineers, scientists, policymakers, and various other stakeholders. It aids in enhancing collaboration, resolving conflicts, and harnessing the diverse expertise necessary for successful project outcomes.

For Green energy projects, the processes that received the lowest ratings based on their average scores are Scope Definition (average score – 2.2), communication planning (average score – 2.9), and Risk Management Planning (average score – 2.5). These findings allow us to reject the first hypothesis: that green energy projects have better performance in risk management processes than low-tech projects. As depicted in Table 3, the risk management planning score for green energy projects (2.5) is lower than for construction (4) and scientific projects (2.7). Effective risk management is essential in green energy projects, which frequently require substantial investments in new technologies, adjustments to regulations, and environmental considerations. It plays a key role in identifying and mitigating potential threats that could affect the efficiency of the project.

Therefore, the study assumes that a low level of risk management may negatively impact efficiency dimensions.

Green projects focus more on Quality planning and Project team management, while construction projects vary by concentrating on schedule, cost, and procurement planning; scientific projects prioritise procurement planning, schedule development, and team management. These findings support the second hypothesis, stating that green energy projects use different PM processes than low-tech projects.

Further, the study examines how the use intensity of PM processes influences projects' efficiency dimensions.

Project efficiency evaluation

The table presents data on different project types, along with their PM score and performance metrics.

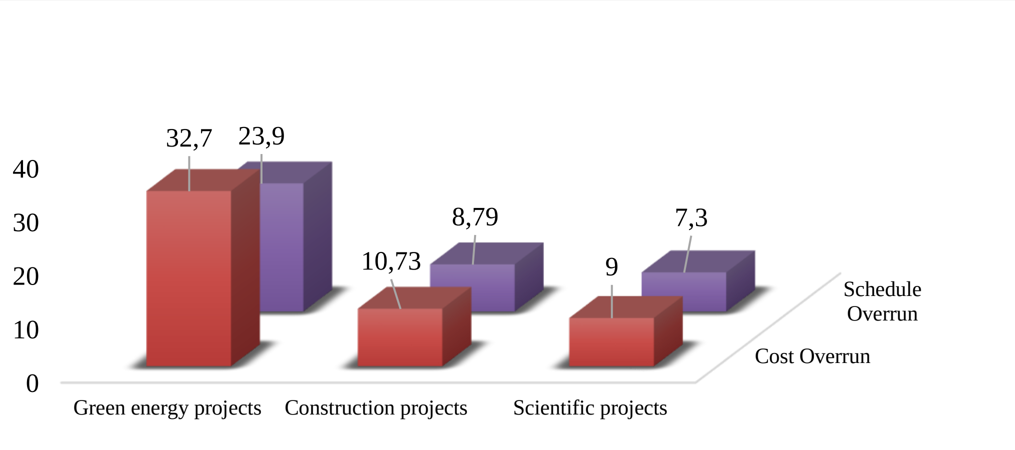

Figure 5: Project efficiency dimensions

As shown in Figure 5, similar to cost overruns, there is a significant divergence in schedule overruns across the project types. Green energy projects exhibit the highest percentage of schedule overruns at 23.9% and cost overrun at 32.7%, indicating substantial delays in project completion and extra expenses in the budget. Construction projects also experience schedule overruns, though comparatively less at 8.79%. Scientific projects demonstrate the lowest percentage of schedule overruns at 7.3%, suggesting better adherence to planned timelines within this category. The data implies that green energy projects face notable challenges in project scheduling, potentially due to the complexity of technologies involved or regulatory hurdles. The complexity of technology can explain these findings because green energy projects frequently incorporate cutting-edge technologies like solar panels, wind turbines, or bioenergy systems. Adopting and utilizing these technologies in practical environments can present unforeseen obstacles and setbacks, ultimately causing increases in expenses and project durations due to the lack of specialists and experience and the absence of their technologies.

Further, figure 6 represents the next project efficiency dimension technical performance ratings.

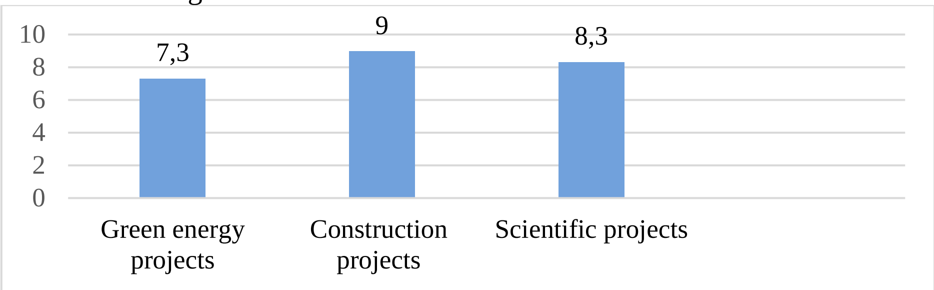

Table 6. The results of technical performance rates

Construction projects typically achieve the highest scores in technical performance (9). Scientific projects also excel at meeting research objectives and producing valuable insights. Conversely, Green Energy Projects often show less favourable outcomes (7.3), despite their extensive use of quality planning processes. Factors such as the complexity of renewable energy technologies, integration issues, or variations in project execution may influence the overall technical performance of green energy projects. These findings lead to **the third hypothesis**, stating that green energy projects' efficiency level is lower than the efficiency of low-tech projects from other industries, as green energy projects have worse results in technical performance, schedule, and cost overruns than the other two projects.

Table 4. Descriptive statistics for green energy project efficiency dimensions

Dimension	Score	Multiple R	Standard deviation	F significance	P-value
Cost overrun	32.7	0.7	25.8	1.09E-05	0.0001
Schedule overrun	23.9	0.6	18.9	0.0003	0.0003
Technical performance	7.3	0.7	1.2	2.18E-05	0.5

These results indicate the statistical significance and direction of influence of each independent variable on the dependent variable in the regression model. For instance, a multiple R of 0.6 and 0.7 indicates a relatively strong positive correlation between the variables. In this context, a small p-value less than 0.05 related to all the efficiency dimensions shows a strong dependence. The multiple R values indicate the strength of these relationships, while the F significance and p-values confirm the overall significance of the regression models for each dimension.

This paragraph aims to identify critical factors affecting the efficiency of green energy projects. The following table presents data related to PM processes, focusing on three key performance indicators (table 5).

Table 5. Critical success factors for green energy project efficiency

	PM process	Cost overrun	Schedule overrun	Technical performance	Critical factor
1	Project plan development	0.002*	0.01*	0.4	+
2	Scope definition	0.11	0.08	0.57	-
3	Schedule development	0.005*	0.7	0.001**	+
4	Cost estimating	0.001**	0.01*	0.02*	+
5	Quality planning	0.04*	0.08	0.02*	+
6	Project team management	0.76	0.68	0.11	-
7	Communication planning	0.006*	0.009*	0.06	+
8	Risk management planning	0.46	0.08	0.31	-
9	Procurement planning	0.77	0.10	0.1	-
10	Stakeholder planning	0.30	0.03	0.4	-
*p≤0.05: **p≤0.001 high significance					

Table 5 provides insights into how different project management processes are associated with a project's cost, schedule, and technical outcomes. Processes with p-values equal to or less than 0.05 and 0.001 were chosen as critical for the efficiency dimensions that enhance it. Thus, project plan development, schedule development, cost estimating, quality planning, and communication planning were revealed to affect project efficiency significantly. It means that the project manager who runs the green energy project should focus on these PM processes to achieve higher efficiency. PMBoK guide provides step-by-step instructions for managing projects according to each knowledge area. These knowledge areas have specific methodologies containing inputs and outputs for the management of projects. The revealed processes are related to specific knowledge areas. Therefore, these findings allow us to prepare the algorithm for efficiently managing green projects.

Conclusion

After thoroughly examining the survey data and research results, the following extended conclusions can be drawn concerning the three research questions.

RQ 1: Which PM processes are critical for green project efficiency dimensions in Kazakhstan?

The research results show that Project plan development, Schedule development, Cost estimating, Quality planning, and Communication planning are critical processes for green project efficiency in Kazakhstan. If project managers from this industry want to achieve high efficiency, they should focus on these knowledge areas when running their projects.

RQ 2: Do PM styles differ in green energy projects and low-tech projects?

Using PM tools varies among selected projects, as green energy projects mainly concentrate on quality and team management, while construction projects show high scores in schedule, cost, and procurement management. Scientific projects focus on procurement, project teams, and schedule management. Only project planning was actively performed in all three projects. The same situation applies to less-used processes. They vary among projects. These differences are explained by the specific characteristics of projects, the differences in infrastructure where they are implemented, and the variance in PM's maturity level.

RQ 3: Is the efficiency of green energy projects less than low-tech projects in Kazakhstan?

As the results show, the efficiency of green energy projects in Kazakhstan is lower than that of low-tech construction and scientific projects. This may be explained by the low use intensity of project management processes, the complexity of such projects, the expensiveness of raw materials, and the lack of skills among human resources. Green energy sources like wind and solar depend on weather conditions, leading to variability in power generation. This intermittency can make matching energy supply with demand challenging, particularly during peak usage.

As for hypothesis, the following three hypotheses were suggested:

H_1 “Green energy projects have better results in performing risk management processes than low-tech projects” was rejected due to the low score of green projects in performing PM processes related to risk management.

H_2 “Green energy projects run using different PM processes than low-tech projects” was accepted because the chosen projects show different maturity levels in performing PM processes, and the knowledge areas where these projects have higher results varied.

H_3 “The efficiency level of green energy projects is lower than the efficiency of low-tech projects from other industries” was accepted due to the low score of green project efficiency dimensions like cost overrun, schedule overrun, and technical performance compared with construction and scientific projects.

Although the study achieved its goals and objectives, some things could be improved. Firstly, the study covered only a limited number of green energy projects from Kazakhstan due to the small country's size and the small number of projects connected with the emerging trend of green energy development, covering only 123 respondents. Secondly, a narrow PM approach to evaluating project efficiency dimensions was used without considering additional factors.

Therefore, future research may expand this study by increasing the number of respondents from the renewable energy industry and covering other countries. Future studies may also compare Kazakhstan's results with other countries' green energy projects. Moreover, new criteria, indicators, or indexes for assessing project efficiency may be used. Alternatively, the authors may use quantitative and qualitative methods to collect more detailed data.

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BADANIE KRYTYCZNYCH CZYNNIKÓW SUKCESU DLA EFEKTYWNOŚCI PROJEKTÓW ZIELONEJ ENERGII

Streszczenie: W ostatnim czasie nastąpił gwałtowny wzrost zainteresowania projektami związanymi z zieloną energią, napędzany ich potencjałem do znacznego zmniejszenia emisji gazów cieplarnianych (GHG) i zmniejszenia zależności od paliw kopalnych. Jednak złożoność, kosztowność i wysoki poziom niepewności takich zaawansowanych technologicznie projektów wymagają nowych sposobów zwiększania efektywności. Dlatego też niniejsze badanie, którego wyraźnym celem jest ocena efektywności projektów związanych z zieloną energią i identyfikacja krytycznych czynników sukcesu, które mogą zwiększyć efektywność, pozostaje ważnym i istotnym przedsięwzięciem badawczym. W badaniu zastosowano rygorystyczną metodologię, wykorzystując analizę regresji wieloliniowej do ankietowania 123 kierowników projektów z Kazachstanu. Pozwoliło to na kompleksowe porównanie poziomu efektywności projektów związanych z zieloną energią i projektów o niskim poziomie zaawansowania technologicznego. Wyniki badań pokazują, że projekty związane z zieloną energią wykazują najwyższy odsetek przekroczeń harmonogramu na poziomie 23,9% i kosztów na poziomie 32,7%, co wskazuje na znaczne opóźnienia w realizacji projektu i dodatkowe wydatki w budżecie w porównaniu z projektami o niskim poziomie zaawansowania technologicznego. Co więcej, projekty związane z zieloną energią wykazują najmniej korzystne wyniki (7,3) w zakresie wydajności technologicznej. Badanie ujawnia następujące krytyczne procesy sukcesu zwiększające efektywność projektu: planowanie projektu, zarządzanie zakresem i kosztami, komunikacja i zarządzanie zespołem. W oparciu o procesy zawarte w przewodniku Project Management Body of Knowledge (PMBoK) opracowano algorytm zarządzania projektami związanymi z zieloną energią. Narzędzie to wyposaża kierowników projektów w mapę opartą na procesach, umożliwiając im efektywne prowadzenie projektów i zwiększanie ich wydajności.

Słowa kluczowe: zarządzanie projektami, projekt zielonej energii, projekt high-tech, energia odnawialna, efektywność projektu