Плазмове наплавлення. Металевий порошок розпилюють плазмовою дугою, створюючи шар товщиною 2–5 мм з твердими карбідами (до 50–60 HRC). Цей метод дає значний приріст ресурсу (в 2–4 рази), але потребує спеціального обладнання. Покриття міцно зв'язане з основою, проте є ризик термічного пошкодження і спікання частинок.

Список використаних джерел

1. Борак К. В. Комплексний підхід підвищення довговічності та зносостійкості робочих органів ґрунтообробних машин : дис. … д-ра. техн. наук : 05.05.11 / Поліський національний університет, м. Житомир. 2021. 380.

2. Борак К. В. Impact of soil moisture on wear intensity of the actuating elements of soil processing machines. Міжнародний науковий журнал «Проблеми трибології». 2020. № 2. С 34–41.

3. Борак К. В. Impact of soil moisture on wear intensity of the actuating elements of soil processing machines. Проблеми трибології. 2020. № 2. С 34–41.

UDC 005.8:504.06

APPLICATION OF PM² IN ENVIRONMENTAL PROJECTS: TOOLS, CHALLENGES, AND PRACTICAL EXAMPLES

V. MELNYK, PhD, Associate Professor
Kherson State Agrarian and Economic University,
National University of Life and Environmental Sciences of Ukraine

The PM² methodology, developed by the European Commission, represents a contemporary project management framework that integrates the structured approach of traditional methodologies, such as PMBOK, with the flexibility of Agile principles (European Commission, 2023). PM² emphasizes transparency, stakeholder collaboration, and adaptability, making it particularly suitable for complex initiatives. In the context of environmental projects, such as ecosystem restoration, waste management, or green energy implementation, PM² provides a systematic approach to achieving sustainable development goals (United Nations, 2015). It encompasses four key phases—initiation, planning, execution, and closure – with a focus on artifacts like the Project Charter, Risk Log, and Stakeholder Matrix (European Commission, 2023).

The relevance of PM² for environmental projects is driven by global challenges, including climate change and biodiversity loss. According to the European Environment Agency, over 65% of environmental initiatives in Europe face delays due to unstructured planning and insufficient stakeholder engagement (European Environment Agency, 2024). Within the European Union, projects must

comply with stringent regulations, such as Directive 2014/52/EU on environmental impact assessment (European Union, 2019). In Ukraine, where environmental projects are often funded through EU programs like EU4Environment, PM² facilitates the integration of national legislation, such as the 2017 Law on Environmental Impact Assessment (Ministry of Environmental Protection, 2022). The objective of this paper is to demonstrate how PM² enhances the efficiency of environmental projects by minimizing risks and optimizing resources. The tasks include analyzing the theoretical foundations of PM², reviewing practical case studies, identifying challenges, and formulating recommendations for Ukraine. The paper is structured to provide a logical progression from theory to practice, concluding with insights and future prospects. PM² is not merely a tool but a philosophy that fosters the transition to sustainable development, enabling projects to adapt to dynamic conditions such as climate change or regulatory updates.

Theoretical Foundations of PM² for Environmental Projects

PM² is grounded in best practices of project management tailored to the European context (European Commission, 2023). Its core components include phases, roles, and artifacts. The initiation phase involves creating the Project Charter, a document that defines objectives, scope, and stakeholders. In environmental projects, this enables clear delineation of environmental impacts, for instance, in land reclamation projects where the Charter includes biodiversity metrics (Krajewska & Nowak, 2022). The planning phase employs the Work Breakdown Structure (WBS) to decompose tasks, the Risk Log to identify risks such as soil contamination, and the Stakeholder Matrix to analyze stakeholders ranging from local communities to regulators (European Commission, 2023).

The execution phase focuses on Monitoring & Control, utilizing tools like the Issue Log to track progress. The closure phase includes the Lessons Learned report, which enhances future projects. PM² defines clear roles: the Project Manager Coordinates activities, the Steering Committee oversees progress, and stakeholders are actively engaged through regular meetings (European Commission, 2023). This distinguishes PM² from PRINCE2, which is more bureaucratic, or pure Agile, which lacks structure for regulatory projects (PRINCE2 Foundation, 2017; Agile Alliance, 2022).

Integration with environmental standards is a key strength of PM². It aligns with ISO 14001, which governs environmental management, enabling the application of PDCA (Plan-Do-Check-Act) cycles in projects (International Organization for Standardization, 2015). Within the EU Green Deal, PM² supports circular economy objectives, such as waste management, where WBS facilitates recycling supply chain planning (European Union, 2019; Van der Meer, 2024). Technologies enhance PM²: IoT for real-time monitoring (e.g., CO2 sensors in green energy projects), GIS for spatial planning and AI for risk forecasting through machine learning models (Martínez & López, 2023).

The advantages of PM² are evident: according to the European Commission, projects using PM² are completed 30% faster with fewer budget deviations (European

Commission, 2023). In environmental contexts, this translates to reduced environmental impact, with optimized resource use lowering emissions by 20–25% (Deloitte, 2023). PM²'s risk management employs the Risk Response Plan; classifying risks by likelihood and impact, with mitigation strategies (avoid, mitigate, and accept). For environmental projects, this is critical, as risks encompass not only financial but also socio-ecological factors, such as community conflicts (Project Management Institute, 2021).

Table 1. Comparison of PM² with Other Methodologies in Environmental Projects

Methodology	Structure	Flexibility	Stakeholder Focus	Benefits for Environmental Projects
PM²	High	Moderate	High	Alignment with EU standards, transparency
PMBOK	High	Low	Moderate	Detailed risk management, less adaptive
Agile	Low	High	High	Fast iterations, lacks structure for regulatory projects
PRINCE2	High	Low	Moderate	Strict control, bureaucratic for dynamic ecosystems

Practical Application of PM² in Environmental Projects

Practical experience demonstrates PM²'s effectiveness in real-world projects. Three case studies are presented below.

Case Study 1: Land Reclamation in Poland

A reclamation project for post-mining areas in Silesia (2018–2022) utilized PM² to restore 500 hectares of land (Krajewska & Nowak, 2022). During the initiation phase, the Project Charter outlined objectives: reducing heavy metal contamination by 70% and implementing reforestation. The Stakeholder Matrix identified key players—local communities, the Ministry of Ecology, and NGOs. Planning involved WBS for stages (soil analysis, bioremediation, monitoring) and a Risk Log addressing risks like weather delays, with mitigation plans (contingency budgets) (European Commission, 2023). Execution used IoT sensors for real-time monitoring. The project was completed 15% under budget, with a 40% increase in floral species diversity (Krajewska & Nowak, 2022). This is relevant for Ukraine's Donbas region, where PM² could coordinate post-conflict reclamation.

Case Study 2: Green Energy in Spain

A solar farm project in Andalusia (2020–2023) applied PM² to install 100 MW of capacity (Martínez & López, 2023). Initiation involved a Charter targeting an 80,000-tonne annual CO2 reduction. The Stakeholder Matrix ensured collaboration

with local farmers and regulators. Planning used WBS for infrastructure (panels, grids) and a Change Management Plan to adapt to updates in the EU Renewable Energy Directive (European Union, 2019). Risks (supply chain, weather) were managed via the Risk Log. Execution included weekly reports and AI for energy output forecasting. The project launched six months ahead of schedule, achieving a 150% ROI (Martínez & López, 2023). In Ukraine, PM² is applicable to solar farms in the Chernobyl Exclusion Zone, where regulatory risks are significant.

Case Study 3: Waste Management in the Netherlands

A circular economy project in Rotterdam (2019–2024) used PM² for plastic waste recycling (Van der Meer, 2024). Initiation involved a Charter aiming to reduce waste by 70%. The Stakeholder Matrix engaged businesses and municipalities. Planning included WBS for logistics and a Decision Log for rapid decisions (e.g., supplier changes). Monitoring & Control utilized IoT for waste tracking (European Commission, 2023). The project reduced plastic waste by 60% and saved €1.5 million (Van der Meer, 2024). In Ukraine, PM² could optimize waste sorting pilots in Kyiv or Lviv.

Challenges: Lack of PM² expertise, stakeholder resistance, and technological barriers. **Solutions**: Training programs, EU partnerships (e.g., Horizon Europe, 2024).

Recommendations for Implementing PM² in Ukraine and Global Perspectives

Adapting PM² in Ukraine requires alignment with national regulations. The 2017 Law on Environmental Impact Assessment can be enhanced with PM² artifacts like the Risk Log for EIA processes (Ministry of Environmental Protection, 2022). Recommendations include developing a national guideline through the Ministry of Environmental Protection using EC PM² templates (European Commission, 2023). Training programs, in collaboration with EU4Environment, should certify project managers. Budget allocation of 5–10% of project costs for PM² implementation is expected to yield returns within one year (Deloitte, 2023).

Stakeholder engagement via the Stakeholder Matrix can coordinate government, NGOs (e.g., Environment-People-Law), and businesses. In the Carpathians, PM² could manage forest restoration projects.

Globally, PM² is becoming a standard for Horizon Europe, targeting climate-neutral cities by 2030 (Horizon Europe, 2024). McKinsey predicts that PM²-like methodologies will attract $2 trillion in green project investments by 2030 (McKinsey & Company, 2025). Ukraine's potential includes reducing project delays by 25% and attracting €500 million in EU funding for green energy and waste management (Ministry of Environmental Protection, 2022).

Conclusions

PM² transforms environmental projects by ensuring structure, transparency, and sustainability. It minimizes risks, optimizes resources, and engages stakeholders, contributing to the Sustainable Development Goals (United Nations, 2015). Its

benefits include compliance with regulations, economic efficiency, and reduced environmental impact (European Union, 2019). Future prospects involve integrating PM² into Ukraine's national strategies and exploring AI synergies (McKinsey & Company, 2025).

References

1. European Commission. (2023). *PM² Project Management Methodology Guide (Version 3.1)*. Publications Office of the European Union.

2. European Environment Agency. (2024). *Environmental project implementation in Europe: Challenges and statistics*. EEA Report No. 15/2024.

3. Horizon Europe. (2024). *Funding for climate-neutral projects*. European Commission.

4. International Organization for Standardization. (2015). *ISO 14001:2015 Environmental management systems*. ISO.

5. Krajewska, A., & Nowak, M. (2022). Reclamation of post-mining areas in Silesia: A case study. *Journal of Environmental Management, 310*, 114789. https://doi.org/10.1016/j.jenvman.2022.114789

6. Martínez, J., & López, R. (2023). Solar farm development in Andalusia using PM². *Renewable Energy, 215*, 118945. https://doi.org/10.1016/j.renene.2023.118945

7. McKinsey & Company. (2025). *Global green investments: Trends to 2030*. McKinsey Sustainability Insights.

8. Ministry of Environmental Protection and Natural Resources of Ukraine. (2022). *Low-carbon development strategy of Ukraine until 2050*. Kyiv: Ministry of Environmental Protection.

9. European Union. (2019). *The European Green Deal*. COM (2019) 640 final.

10. Project Management Institute. (2021). *A Guide to the Project Management Body of Knowledge (PMBOK Guide)* (7th ed.). PMI.

11. PRINCE2 Foundation. (2017). *Managing Successful Projects with PRINCE2*. AXELOS.

12. Agile Alliance. (2022). *Agile Manifesto and Principles*. Agile Alliance.

13. United Nations. (2015). *Sustainable Development Goals*. United Nations Department of Economic and Social Affairs.

14. Van der Meer, L. (2024). Circular economy in waste management: Rotterdam project. *Waste Management, 178*, 45–56. https://doi.org/10.1016/j.wasman.2024.01.012

15. Deloitte. (2023). *Project management methodologies in sustainability initiatives*. Deloitte Insights.