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**GERAD** HEC Montréal
3000, chemin de la Côte-Sainte-Catherine
Montréal (Québec) Canada H3T 2A7

**Tél. : 514 340-6053**
Téléc. : 514 340-5665
info@gerad.ca
www.gerad.ca

# A digital transformation project portfolio management model for underground mines

**Marine Echternach-Jaubert** [a, b]

**Robert Pellerin** [a, b]

**Michel Gamache** [a, b]

[a] *GERAD, Montréal (Qc), Canada, H3T 1J4*

[b] *Département de mathématiques et de génie industriel, Polytechnique Montréal, Montréal (Qc), Canada, H3T 1J4*

marine.echternach-jaubert@polymtl.ca
michel.gamache@polymtl.ca

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**Abstract :** This paper addresses the difficulties mining companies face in planning their digital transformation. Based on the literature on project portfolio management and digital transformation, we propose a project portfolio management model adapted to the mining industry that aims at aligning the value of the digital transformation projects with the desired strategic outcomes of the Smart Mine. This paper focuses on the initiative's identification phase, divided into portfolio, program, and project levels. The model, which has not been tested yet, follows the academic and industrial best practices to answer the mining specificities, including risk management, communication and stakeholder management, and change management.

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# 1 Introduction

Contrary to manufacturing companies with fixed production lines, underground mines are under continuous construction and constant expansion without a continuous process. The underground mining industry is a unique and complex environment that faces several challenges, including a dynamic environment, safety concerns, high uncertainty, remote locations, extreme climates, confined space, technology and infrastructure scalability, and limited mine lifespan [1, 2]. To address productivity issues [3] and an aging workforce [4], the mining industry slowly started its digital transformation [5] with the ultimate goal of achieving the Smart Mine concept. Mining practitioners define a Smart Mine as a digitally connected, sustainable, autonomous, and human-centered organization [6, 7]. The objectives, suggested solutions, and targeted business processes of the underground Smart Mine have been defined in previous work to clarify where the mining industry is heading [8].

Due to the specific characteristics of each mine, there is no one-size-fits-all solution to attain the Smart Mine and the literature does not provide specific guidance in achieving it [9, 10]. Most digital transformation strategies are technology-centric roadmap [11, 12] and ignore the multi-project interdependency dimension required for the mining industry. To align with the mining industry priorities, reduce operating costs, and improve productivity and safety, the underground mines sector needs an operational model that includes the mining challenges to guide them through the digital transformation. This paper addresses this issue by proposing a digital transformation project portfolio management model adapted to the current needs of the mining industry. The rest of the paper is organized as follows. Section 2 covers the literature review relevant to digital transformation project management. The proposed model is then presented in Section 3 before concluding the paper with a review of the main contributions of this article and a presentation of research avenues.

# 2 Literature review

The scientific literature offers roadmaps, canvas, maturity, readiness models, and project portfolio management best practices and models.

Schumacher et al. [13] developed a ten-step maturity assessment procedure to create company-specific roadmaps. The initiatives are evaluated during workshops to determine responsibilities, timelines, and resources. Sarvari et al. [14] presented a technology roadmap in two phases: strategy and development of new products and processes. The strategy phase evaluates the enterprise's digital maturity to set clear targets. The author uses experts to generate ideas as initiatives. De Carolis et al. [15] proposed digital transformation roadmap based on the Digital Readiness Assessment Maturity model. The model is used to assess the current readiness of manufacturing companies and identify opportunities based on their strengths and weaknesses regarding technology implementation and organizational processes. Mielli and Bulanda [16] outline an operational digital transformation roadmap in 8 steps: examine the current state, develop a future vision, identify opportunity, document and define quick wins and return on investment, commit to projects, pilot, scale, and review and assess results. Ghobakhloo et al. [17] extracted recommendations from SME-Industry 4.0 technology adoption scientific articles to establish a technology adoption roadmap. The roadmap is broken down into five conditions: knowledge competencies focusing on human resources, assessing technology maturity and readiness, assessing the readiness of the supply chain, managerial competencies, and external collaboration for Industry 4.0 transformation. Al-Banna et al. [18] suggested a roadmap in 5 steps for digital supply chain resilience: conduct a self-assessment to identify the pain points and root causes, identify the drivers to combat the pain points, identify I4.0 solutions with an evaluation process, verify the solutions to filter out technologies, and finally implement the I4.0 solutions with KPIs created and ROI targets. Barbosa et al. [19] created an operational R&D roadmap to assist a multidisciplinary work team with process robotization using the Plan-Do-Check-Act (PDCA) method. The first step is to form a multidisciplinary team from different departments and evaluate the current process. Basulo-

Rebeiro et al. [20] created a roadmap for digital transformation based on management and process methodologies and developed a web application to support the Plan phase of the roadmap.

Lemieux et al. [21] proposed an adoption alignment framework to identify and prioritize agility improvement initiatives in product development in the luxury industry. The framework is composed of four layers, from strategic to transformation initiatives. The authors use a maturity assessment matrix to identify initiatives. Butt [22] created a conceptual framework to support digital transformation in manufacturing using an integrated business process management approach structured in ten defined phases. Phases include process analysis and reengineering, business process streamlining, risk management, skill gap analysis, change management, and cost-benefit analysis. However, the framework does not include project interdependency and lifespan. Echternach et al. [8] developed a generic transformation initiatives alignment framework to guide mining companies in their digital transformation. The framework suggests a top-down and bottom-up approach to ensure initiatives are aligned with the Smart Mine objectives.

Bellantuono et al. [23] analyzed the digital transformation models from the scientific literature under the lens of change management models. None provide a complete model to support organizations in the digital transformation process. The authors provided recommendations regarding change management. Heberle et al. [24] developed a standardized digitalization canvas with a top-down, bottom-up approach and concrete steps to define digital transformation projects. This led to an initial version of a portfolio of projects roughly estimated and prioritized. The Project Management Institute's best practices suggest including stakeholder and communication management, risk management, and change management in the portfolio project management [25]. Richard et al. [26] proposed a project portfolio management model to support the digital transformation of manufacturing companies. The model contains six phases: identification, categorization, evaluation, selection, prioritization, and balance, including activities, roles, techniques, and deliverables, to help align industry 4.0 initiatives to meet the company's strategic goals and objectives.

Table 1 compares all these models based on the mining industry's challenges and portfolio management best practices. The existing portfolio management literature does not include best practices that have been adapted to mining challenges.

**Table 1: Critical analysis of the relevant articles**

| Articles | Portfolio management model | Maturity and readiness model | Roadmap/ Steps | Canvas/ Framework | Guidelines/ Recommendations | Operational model | Scalability | Lifespan | Project Interdependency | Risk management | Communication and stakeholder management | Change management |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [8] | | | | x | | x | x | x | | | | |
| [13] | | x | x | | | x | | | | | | |
| [14] | x | | x | | | | | | | | | |
| [15] | | | x | | | x | | | | | | |
| [16] | | | x | | | x | | | | x | | |
| [17] | | | x | | | | | | | | x | |
| [18] | | | x | | | x | x | x | | | | |
| [19] | | | x | | | x | | | x | | x | |
| [20] | | | x | | | x | | | | | | |
| [21] | | | | x | | x | | | | | | |
| [22] | | | | x | | | | | x | x | x | x |
| [23] | | | | | x | | | | | | | x |
| [24] | | | | x | | x | | | | | | |
| [26] | x | | | | | x | | | x | x | | |
| [37] | x | | | | | | | | x | x | x | x |

# 3 A project portfolio management model

This research focuses on building the first project portfolio management model adapted to the mining industry. This paper focuses only on the identification phase to identify initiatives for digital transformation. To achieve this objective, we follow a three-step methodology. First, we extracted articles addressing project portfolio management and digital transformation models from the scientific literature, as presented in Section 2. Literature from various databases using Scopus, Web of Science, and IEEE were used. Second, best practices from the literature and mining practitioners were integrated to answer underground mining operations challenges to propose a project portfolio management model, as exposed in the following section. Our model follows the phases proposed by Richard et al. [26]. Third, a field analysis based on mining experts' feedback on the industry's use and the potential value-added of proposed activities allows us to build our final model adapted to the mining industry.

The proposed model includes the three levels of portfolio management: portfolio, programs, and projects. The model includes communication and stakeholder management, risk management, and change management areas [25]. Before starting, the company's strategic objectives, as well as the Smart Mine objectives, need to be known and written. The general model is presented in Figure 1. Grey cases represent the portfolio level, orange represents the program level, and yellow represents the project level. Blue cases are related to change management, green to risk management, and red to communication *and* stakeholder management activities. Plain cases are steps existing in previous models, italics represent a novelty adapted to the mining sector, and dashes represent existing steps in previous models but for which the order was changed.

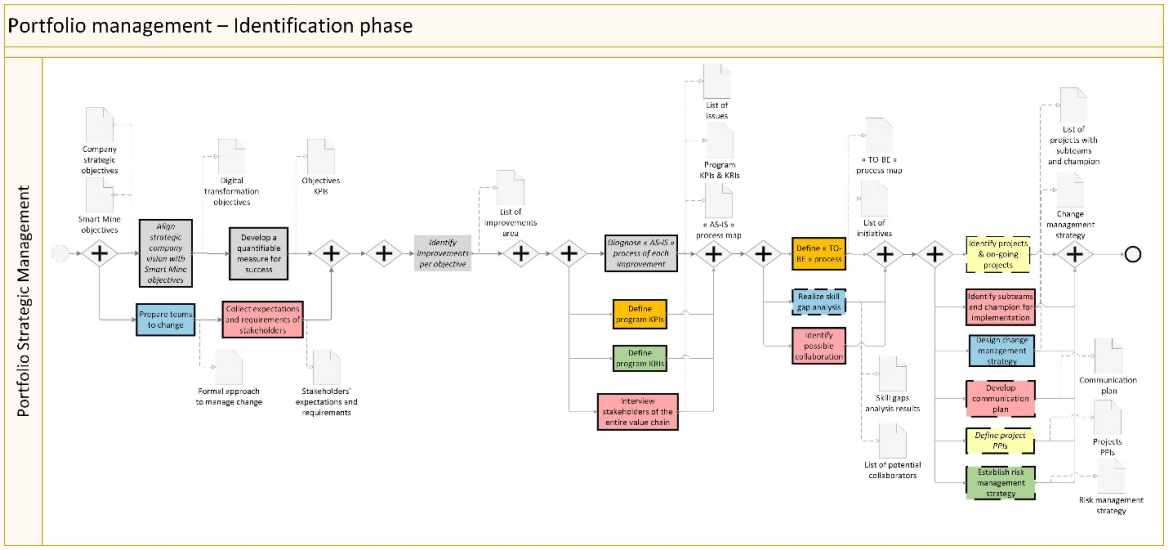


**Figure 1: Identification phase project portfolio management model**

**Step 1:** Academics and industrials agree that the primary step is defining, identifying objectives, and establishing the company's strategy and vision. The first step is to align the company's strategic objectives with the Smart Mine objectives, which create multiple digital transformation objectives that are the final goals the company wants to reach. Smart Mine's objectives are described in the literature [8]. To establish the company's strategy and vision, Barbosa et al. [19] suggest putting together a multidisciplinary team as well as collecting the expectations and requirements of internal and external stakeholders [22]. This phase can be supported by undertaking a SWOT (Strength-Weakness-Opportunity-Threat) analysis and workshops [12, 15, 28, 29, 31]. Sarvari et al. [14] evaluate digital maturity to set clear targets based on the time horizon [11, 17, 31] and De Carolis et al. [15] assess the organization's technical readiness [17, 27, 30]. Change management is a primary consideration through all the stages, so when objectives are

defined, the organization's culture needs to move toward change [27, 32, 33]. The output of this activity is a formal approach to managing change by collecting data and opinions from the entire organization [22].

**Step 2:** Lemieux et al. [21] suggest translating the objectives into Key Performance Indicators (KPIs) [22, 27, 29, 30]. The second step is to define a quantifiable measure for success as KPIs based on the digital transformation objectives. All the indicators should satisfy the SMART (specific, measurable, assignable, realistic, time-related) criteria.

**Step 3:** The third step is specific to the mining industry. In general, the mining industry is primarily solution-centric, relying on Original Equipment Manufacturers (OEMs) and suppliers' solutions. To achieve the Smart Mine, the mining industry needs to lead the development of new ideas and solutions before identifying a technology. Epiroc [33] suggests a bottom-up OEM-agnostic approach. Solutions will differ depending on the location and type of the mine. Bechtold et al. [31] advice to analyze areas for improvement [30]. At this step, we do not choose a specific technology but identify the area of improvements per digital transformation objectives based on the Smart Mine solution and targeted business processes, which can be found in the work of [8]. Improvements can be qualitative or quantitative. This step leads to a list of improvement areas per objective. At this stage, the interdependency between objectives and solutions will start to be revealed.

**Step 4:** Mielli and Bulanda [16] examine the current state [19, 23, 27, 29, 30], identify the business processes [22] and assets [11], and analyze the mapped "AS-IS" process. This step includes defining KPIs and Key Risks Indicators (KRIs) that are consistent with the organization's vision [22]. For Richard et al. [26], business process analysis was a prerequisite. Schumacher et al. [13] assesses the maturity of eight dimensions for Industry 4.0. Our fourth step is to diagnose (identify and analyze) the "AS-IS" process in terms of infrastructure, technology, process, workforce, and equipment of each improvement area identified in Step 3. This step includes two essential activities: data collection and process modeling. Different standards and tools are available to map the process, from manual to software [20, 22]. This step allows us to detect process issues and inconsistencies regarding the objectives in the current processes, define KPIs and KRIs, and recommend effective modifications. Al- Banna et al. [18] identifies pain points and problems with root-cause analysis [26]. During this step, associations and dependencies between processes are analyzed. While the processes are analyzed and KPIs and KRIs are defined, Heberle et al. [24] recommends interviewing experts on each part of the "AS-IS" process value chain to define realistic KPIs that reflect the objectives and identify issues.

**Step 5:** Butt [22] suggests identifying changes to the process to address the issues identified in Step 4. Step 5 defines the "TO-BE" process in identifying initiatives to solve detected problems in Step 4 to achieve the defined program KPIs. Those initiatives will constitute the program level. Al-Banna et al. [18] use Industry 4.0 technologies to identify technology-focused strategies to align the initiatives with the organizational strategy [22, 26]. Multiple methods are available to identify initiatives. Lemieux et al. [21] use a maturity matrix to underline the level of adoption of various defined areas, while Heberle et al. [24] use a Digitalization Canvas, and Moodley [28] suggests benchmarking existing technologies in adjacent organization's peers. Before implementing new technologies, it is important to improve existing processes, and sometimes technology is not necessary [27]. Once the "TO-BE" process has been defined, it is important to streamline the involved business processes from the entire value chain [17]. During this step, it is essential to carry out an impact analysis for each initiative to determine how close to the defined objectives KPIs this process brings the company. The study will determine if more than one initiative needs to be realized to achieve the objectives. External collaboration with clients, suppliers, technology partners, and competitors is recommended [14, 17]. Butt [22] suggests realizing a skill gaps analysis [23], and Jacobs et al. [11] use digital maturity assessment to understand organizational capability.

**Step 6:** Ernst and Young [12] suggests defining projects that consider long-term strategy. Richard et al. [26] collects information on ongoing projects. The sixth step is to identify projects from the list of initiatives, skill gap analysis, and ongoing projects. For each project, Butt [22] suggests defining Process Performance Indicators (PPIs) to measure the operational success of the project based on program KPIs to ensure the alignment of the objectives. As the mining industry requires scalability of projects [33], it is important to define the PPI minimum threshold until this project is no longer considered part of the portfolio. At that time, Lemieux et al. [21] suggests determining the transition team responsible for project implementation [23], and Harris [32] suggests identifying a champion for each project and developing a communication plan. Butt [22] suggests at that point to determine a risk management strategy. Effective communication is primordial to ensure a successful digital transformation [22], best practices suggest developing a communication plan to support change management [25, 32], especially to stakeholders [23].

# 4 Conclusion

This model is the first operational approach to the project portfolio management identification phase adapted to the mining industry for digital transformation. Our model consists of the best practices from both industrial and academics, including risk management, change management, and communication and stakeholder management. The model includes the different portfolio levels, programs, and projects, revealing interdependency in the following phases. It is important to note that top management commitment and a human-centric approach are mandatory to achieve a successful digital transformation. Unlike maturity assessment models, our model uses a broader approach to defining project alternatives. The scalability, the lifespan of the mine, project interdependency, and return on investment are significant constraints, and some initiatives should be disregarded or put aside for later consideration. Using this model will allow mining companies to not depend on OEM solutions or technology-centric roadmaps from consulting companies but identify projects aligned with their strategic and Smart Mine objectives. Still, our proposed approach has not yet been fully defined, and further research is planned to elaborate on the different phases and validate the model by mining practitioners with a Delphi-Regnier analysis.

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