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Review Article

Analysis of the Relationship Between Engineering Project Management and Engineering Product Development: A Review

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Abstract

This study explores the two distinct parts of engineering management: engineering product management and engineering project management. A qualitative systematic review method was employed, using purposively sampled literature and a desk-based research approach. Using thematic analysis, the researchers produced significant data findings. The findings suggest that Engineering Project Management and Engineering Product Development play a vital role in achieving success in engineering projects. While they possess distinct principles, practices, and concepts, they share important management techniques in the business realm. The findings also indicate significant disparities in methods, utility and resource allocation, and quality assurance while highlighting the absence of administrative functions in Engineering Product Development compared to Engineering Project Management. Furthermore, the study notes that greater creativity and efficiency in both management practices are enabled by current technology and methodology. The study's limitations include an extensive use of literature review data and a focus on a broad target area. Consequently, this suggests a need for empirical data to enhance experience-based research and to focus on a specific industry for more precise outcomes.

1. Introduction

Engineering Project Management (EPM) and Engineering Product Management and Development (EPD) are distinct yet interrelated fields within the broader realm of engineering [1]. Over time, project management has consistently gained recognition as a significant and distinct component of project administration. With industry modernisation, a new form of management called product management and development has emerged to aid in the creation of competitive consumer goods[2]. Engineering project management (EPM) plays a crucial role in the strategic organisation, conceptualisation, financial allocation, time

management, and implementation of projects aimed at addressing and effectively handling societal issues, problems, and intricacies [3]. A project manager is responsible for organising people, budgets, timetables, and other related duties [4].

Engineering product development (EPD) is the comprehensive process of conceiving, creating, producing, and enhancing engineering goods. These products can include a diverse array of digital and physical entities or solutions. The product development team actively collaborates to finalise the product's design. This entails the transfer and dissemination of design information and innovative ideas among team members [3], [5]. A product developer is primarily concerned with developing a product, from the first idea to its final execution. They place a greater emphasis on understanding and meeting the user's requirements. Research suggests that the project manager function may evolve into the product manager role as firms recognise the growing importance of product managers [2].

Currently, the importance of EPM in developing new products and maintaining a competitive edge clouds judgment in appreciating its striking relationship with EPD [6]. Project administration and management primarily prioritise the efficient implementation of engineering projects, while product management and development place greater emphasis on the creation and enhancement of engineering products. Identifying and defining a clear relationship increases the understanding of these domains for engineers and organisations seeking to maximise operational efficiency and effectiveness in delivering high-quality products. Consequently, this enhances the effectiveness of engineering efforts in product development and team management. Several studies have described the independent domains, but only a limited number have considered the relationships in terms of similarities and differences, highlighting the difficulty in understanding the distinctions and relationships between project and product development [2]. These aspects are essential for understanding the significance of each discipline in providing new interventions for society and communities.

Therefore, this study aims to explore the relationships existing between EPM and EPD to ascertain their commonalities, distinctions, and ramifications for the engineering sector. Breaking down the study aim, we identified the following objectives: (1) identifying the key principles, concepts, and practices related to EPD and EPM, including methods, resource allocation, and utility; (2) identifying risk management and quality assurance practices; and (3) guiding productivity and growth improvement.

2. Literature Review

2.1. Concept of Engineering Project Management and Engineering Product Development

According to [7], EPM has transformed to effectively plan, coordinate, and oversee intricate and varied tasks, making it more applicable to information technology, business, industrial, and managerial initiatives. All initiatives share the trait of translating ideas and actions into new ventures. Engineering

projects involve key operations such as formulating system specifications, creating prototypes, designing systems, evaluating specifications and prototypes, assessing designs, and performing final operational testing [7]. In addition, EPD, a significant component of Concurrent Engineering (CE), allows for the timely manufacturing of a product following the agreed-upon timescale among all relevant stakeholders [4]. As a result, in EPD, CE plays a larger role in achieving milestones compared to convention-al methods. This is because CE necessitates a team approach to move from a thorough design specification or customer requirement to manufacturing a functional prototype [4]. Research revealed that the processes of product development and project management share a common component: managing the requirements, input, and interests of numerous stakeholders [8]. Furthermore, the stakeholder theory emphasises that successful project management necessitates considering the diverse interests and requirements of the involved stakeholders [9]. Aside from this, resource-based theory emphasises the im-portance of managing physical, financial, and human resources while developing a product and managing any project [9].

2.2. Risk Management and Quality Assurance in Engineering Project Management and Engineering Product Development

As stated by [10], risk management, and quality assurance are critical procedures in EPD and EPM. According to [11], quality assurance and risk management are closely related disciplines in any organisation. The statement suggests that risk management and quality assurance objectives are similar in both domains, but the timing and emphasis of these practices differ [12]. [13] concurred, noting that the variations in the characteristics of risk reduction and quality assurance procedures were because project management and product development are two separate processes. Risk management and quality assurance are integral ongoing processes in project management, spanning the whole product development lifecycle and interconnecting the protection of the organisation's welfare [12], [13].

Risk management in EPD involves identifying potential hazards, devising strategies to mitigate them, and monitoring them continuously throughout the project. The desire to innovate and the need to create marketable products are the driving forces behind product engineering and development. It calls for close attention to design details and market dynamics [13]. Moreover, engineering product development centers risk management on the intricacies of product design, the unpredictable nature of technology, and market acceptance. Finding possible risks in the development cycle, such as production difficulties, design defects, or changes in customer preferences, is part of the process. However, risk management is a more comprehensive strategic process that includes locating, evaluating, and averting possible hazards that might influence organisational goals.

In EPD, quality assurance ensures that the product satisfies predetermined requirements and standards. Strict prototyping, testing, and validation procedures ensure the finished product complies with user requirements and design goals. The major goal of quality assurance operations is to maintain high standards in product development processes and deliverables, such as design reviews, testing, and documentation. However, the goal of quality assurance activities in project management is to uphold strict guidelines for project procedures and deliverables, including documentation, testing, and code reviews [10].

EPM, on the other hand, focuses on managing resources, deadlines, and budgetary constraints to execute projects efficiently [13]. Engineering project management handles hazards related to project planning, execution, and completion [14]. In EPM, risk management practices consider variables such as changes in project scope, financial limitations, and unforeseen difficulties in allocating resources. Preventing delays in project time frames and going over budget entails identifying, analysing, and mitigating potential risks. EPM quality assurance relies on project management methods and compliance with the established guidelines and requirements. This calls for ongoing monitoring, assessment of project deliverables, and adherence to industry standards to ensure the project's overall success.

2.3. Organisational Status for Improvement of Productivity and Growth

Organisations require proficient workers and a well-defined strategy to achieve success in any business endeavor [25]. In engineering organisations, creating an environment and culture that promotes high productivity among engineers is particularly important. Establishing and adhering to a plan is key to facilitating mutual understanding and alignment of team members with the organisation's ultimate objectives. According to [4, 9], it is crucial to foster a collaborative culture, acknowledge the mutually beneficial connection between project management and product development teams, and promote interdisciplinary collaboration. Therefore, fostering efficiency and synergy guarantees the alignment of product development innovations with project goals.

Streamlining operations, allocating resources, evaluating essential metrics to assess software development effectiveness, and holding regular retrospectives to pinpoint bottlenecks and recommend improvements are useful for increasing overall productivity and efficiency [17]. Other strategies include assessing current productivity and efficiency, identifying obstacles to offering solutions, and promoting continuous education and career advancement for project and product management team members. The team should make decisions, distribute resources, and implement efficient processes.

3. Research Methods

This study utilises an exploratory research approach that embraces interpretivism. Interpretivism is chosen because it considers subjective perspectives regarding the relationship between EPD and EPM [19].

An inductive approach was employed to promote a bottom-up investigation of the topic to align with the study's aims and objectives. By utilising detailed data on project management, project development methodologies, and resource allocation, particular observations have been made on engineering projects. The study employed a qualitative research methodology to analyse and explain the commonalities and distinctions between EPM and EPD [20].

This study used a secondary data collection strategy to get a more diverse set of subjective and empirical results. The desk research approach has gathered information on EPM and EPD, including topics like resource allocation, usefulness, quality, and risk management. Academic databases made it possible to access and analyse published resources such as journal papers, novels, reputable reports, and other literary sources [21]. Finding relevant publications was the next step, starting with searching academic databases.

3.1. Search Strategy

A search strategy refers to a systematic arrangement of essential terms employed to explore a database [22]. The process started with the definition of the research question, "What are the similarities and differences between EPM and EPD?" This helped to create a sense of scope and define the focus. Three academic databases, including ProQuest, Sage, and PubMed, were utilised to gather data through the desk research approach. Also, the relevant sources were searched using specific keywords combined with boolean operators to precisely describe the search terms [22]. The keywords include "Project Management", "Project Development-", "Engineering Projects", "Project Management Methods in the Engineering Field", "Product Development Method in the Engineering Field", "Risk Management and Quality Assurance", and "Resource Allocation and Utility". All these keywords are collated. The initial search identified 54 papers (ProQuest-22, Sage-12, PubMed-20). The articles retrieved from these databases were analysed using inclusion and exclusion criteria. The study follows these inclusion/exclusion criteria shown in Table 1.

Table 1. Inclusion/Exclusion Criteria.

Criteria	Inclusion	Exclusion
Year Range	Articles published from 2015 – 2022 were included to provide current information.	Excluded are articles that are old or published before 2015
Language	Only articles that are available in the English language are included.	Articles available in any other language than English are excluded.
Credibility	Only articles published in peer-reviewed and reputable publications have been chosen to ensure the credibility of the findings.	Articles sourced from blogs, Wikipedia, or student thesis papers have been excluded.
Relevance	The study included articles that focused on project management and engineering projects.	The study excluded articles not directly associated with project management regimes.

The search and screening process, involving the academic databases, aimed to enhance the research's credibility. Following the screening, the data analysis included a total of 11 articles. The collected qualitative data was organised in a spreadsheet using Microsoft Excel. A thematic analysis method was considered the best way to look at the data in-depth and find common codes and patterns that could be used to find themes [23]. Codes connote the smallest unit used for analysis, which captures some unique data pertinent to the research questions. The research uses these codes as building blocks to generate themes, meaningful patterns, and a core idea shared among the themes.

3.2. Limitations of Research

The key limitations that were faced in this research are outlined below:

- Exclusive reliance on the secondary data collection method of desk-based research.
- Use of a broad target area, which is limited to a theoretical and general subject context.

4. Results and Discussions

4.1. Thematic Analysis and Findings

Thematic analysis was considered to uncover patterns in the data's meaning relevant to the research question and data availability. These identified patterns were categorised into broad, predefined themes to gain deeper insight. The research then analysed the collected data and categorised them under three predefined themes. These predefined themes were derived based on the key research objectives of this study.

4.1.1. Theme 1: Concept and Practices Associated with Engineering Project Management and Engineering Product Development

The secondary evidence reveals significant areas of correlation and disparity in the conceptions and practices associated with EPM and EPD. The EPM involves the seamless planning, organising, and execution of the product development phase while effectively managing resources. The EPD primarily focuses on the systematic creation or upgrading of products, covering the stages of conceptualisation design, manufacturing, testing (from ideation to design, the blueprint to prototyping), and final production [24].

Both processes and applications necessitate the inclusion of the entire and pertinent team to ensure that client requirements, market demand, and regulatory norms are met. Collaboration and communication are essential strategies that connect product development with project management. The teams engaged in cross-functional activities possess a wide range of experience, enabling them to interact effortlessly and

exchange valuable ideas and knowledge throughout the project and product development process. Effective communication is crucial for transferring project goals, timelines, and expectations and preventing misunderstandings. Collaboration and communication help promote a cohesive working environment [17].

EPM and EPD often organise their concepts and methods in stages, focusing on transitioning the idea into the realisation phase in their respective roles. A key concept in product development is the stage-gate model, which involves dividing the process into many phases and reviewing the product at each stage before progressing to the next [25]. Along with the points mentioned, continuous development is another essential practice in EPM and EPD. It enables gradual improvements to respond to changing, challenging, and unforeseen adverse situations and facilitates continuous feedback, flexibility, and adaptability [26]. Evidence shows that EPM and EPD commonly deploy practices such as risk management, resource allocation, communication, collaboration, continuous development, coordination, and integration of modern technologies.

Resource allocation involves actions to reschedule project tasks to maximise the efficient use of limited resources while minimising any necessary project expansion. Large-scale construction engineering projects employ a wide range of methods and resource allocation, which are crucial to EPM due to the involvement of a diverse range of resources, technologies, people, processes, and activities [27]. Thus, in EPM, a decentralised approach is used for resource allocation [28] and involves methods such as agile scrum, system management, agile management, waterfall, and PRINCE2® (Projects IN Controlled Environments). This way, EPM maintains high utility for ensuring smooth progress, keeping work on schedule, and meeting predefined objectives. In contrast, resource allocation in EPD refers to the distribution and assignment of resources such as financial resources, time, materials, and manpower for distinct tasks and activities within the project [29]. Thus, aspects such as project planning, work breakdown structure, prioritisation of key tasks, and monitoring and controlling are highly useful. [30] emphasised that the value of EPD rests in its capacity to transform conceptual thoughts into tangible products via a systematic process and optimises resources for research, designing, testing, and prototyping.

4.1.2. Theme 2: Risk Management and Quality Assurance Practices

Recently, organisations have been known to function in a highly intricate and ever-changing environment where the emphasis on quality has become crucial for their competitiveness, expansion, and survival.

Several dimensions ensure product quality, including features, performance, reliability, durability, serviceability, conformance, aesthetics, and perceived quality. According to reports, the implementation of Total Quality Management (TQM) is receiving considerable attention to improve product design and control processes and create high-quality products [31]. Project managers employ a comprehensive application of statistical quality control to ensure project quality measures. It monitors and regulates processes and product quality, ensuring high standards [32]. The key components involve data collection and analysis, process control, statistical sampling, Six Sigma methodology, root cause analysis, quality metrics like Key Performance Indicators (KPIs), continuous improvement, and standardisation.

Furthermore, studies have shown that implementing idea-to-launch approaches, such as the Stage-Gate system, has garnered attention for ensuring product quality throughout the EPD process [8]. The key components consist of five or six stages and gates, which serve as quality control checkpoints; for example, idea screen, 2nd screen, go-to-development, go-to-test, go-to-launch, and post-launch review [8]. These gates allocate project resources and approve subsequent stages. The result was enhanced collaboration, reduced need for revisions and rework, early identification of failures, and decreased cycle durations [33].

Risk management is another vital component of EPM and EPD. It entails identifying potential risks and impacts, establishing effective mitigation techniques, and ensuring the project stays on schedule. Upon this, [34] suggested using fuzzy logic for project risk assessment. They also introduced RIPRAN™, a risk analysis method that involves decomposing the total risk value into individual components to improve the accuracy of calculations. It enables a numerical distribution of hazards and encompasses all the variables that influence the process of assigning risk. Another focus was placed on Business Information Management (BIM) as a crucial strategy for reducing project risk, which proves more effective when the risks are explicitly identified and articulated [35]. It entails organising and creating a digital data repository for a construction project. BIM efficiently mitigates risks related to cost, time, and schedule. By effectively managing information, BIM enables efficient collaboration among project team members, allowing for comprehensive project monitoring [35]. In EPD, it is inherent to recognise and accept the existence of uncertainty. Incorporating contemporary technology and simulation tools has streamlined virtual prototyping, allowing engineers to evaluate and modify the product before creating actual prototypes and products. These factors reduce expenses and expedite all procedures [36], [37].

4.1.3. Theme 3: Productivity Improvement and Growth

According to research, teams are critical organisational units for conducting engineering projects. A team structure combines business and process knowledge with design and programming skills to effectively guide team members in EPM and EPD. Additional research found that agile project management methods improve team adaptation and responsiveness to project demands [38]. Recent research indicates that agile software development has promoted self-managing software teams. Self-managing teams in software engineering projects boost productivity, employee satisfaction, innovation, and decision-making authority to handle operational issues and uncertainties. This enhances problem-solving efficiency and accuracy [39]. In addition, [40] emphasised the importance of promoting self-management teams to enhance EPM and EPD. Another study revealed the necessity of educating engineering project managers and team members on modern techniques. This education is necessary to increase the chances of completing projects and achieving the expected advantages [34]. To improve communication, streamline workflows, and monitor project progress in real time, it is crucial to use modern project management solutions.

The application of strategic planning and a robust organisational structure were found to be important for directing teams, enhancing productivity, and promoting expansion. In this regard, the project manager should define short-term and long-term goals in alignment with the project's mission, vision, and market analysis [41]. Also, fostering a flat organisational structure and cross-functional teams helps bring diverse expertise to the project level, improve communication, and speed up decision-making.

4.2. Discussion of Key Findings

In the current section, a detailed discussion of findings drawn from the thematic analysis was used to synthesise the data on EPM and EPD. The findings show tangible relationships—both similarities and differences between EPM and EPD.

4.2.1. Similarities

The two managerial components exhibited a resemblance in concepts: risk management, resource allocation, collaboration, and communication, focusing on the ongoing advancement and integration of cutting-edge technology such as simulation tools and virtual prototyping.

The study looked at the main ideas, principles, and practices behind EPM and EPD. Both product development and project management concepts are critical for a successful engineering project's execution.

The study found that both EPM and EPD encompass a range of procedures throughout the whole lifecycle of products and projects. Despite their differences, these management methods have comparable functions. This finding supports [7], [36], who noted that both strategies entail transforming ideas and activities into actual results. The findings show that the two methods require the involvement, integration, and management of several disciplines as team members, their collaboration, and effective communication to meet the customers' changing market requirements, as mentioned in the previous study [4], [8], [42].

Both concepts are organised in production phases for ease of delivery. Organisations usually follow core processes related to risk management and resource allocation to meet demands and deadlines. Continuous development is an essential methodology in EPM and EPD, and it plays a vital role in producing engineering products. This system offers ongoing feedback, enabling flexibility and adaptability. It can offer incremental improvements that help to tackle complex situations and uncertainties, which often define the nature of engineering goods and are essential for achieving successful breakthroughs [26].

In terms of risk management, risk assessment is critical for the success of both the EPM and EPD processes. Both methods recognise BIM as valuable for assessing risks related to time, scheduling, and cost. Such technology allows for equal risk management implementation in both practices. Therefore, risk management and quality management approaches in EPM and EPD differ in many aspects and have similarities in others.

Finally, the study found that both practices have implications for engineering projects. Team cohesion has been observed to significantly contribute to promoting high team productivity, functioning as a crucial organisational component. Another important factor is the emphasis on adherence to plans. Coordinating software engineering projects offers several benefits, including enhanced productivity, employee satisfaction, innovation, and the delegation of decision-making authority to address operational challenges and uncertainties. This ultimately improves the efficiency and accuracy of problem-solving [39]. Developing self-managing teams is necessary to improve EPM and EPD [40]. To build the team, it is essential to prioritise the delivery of clear and engaging instructions, the creation of a well-organised performance unit, a supportive organisational atmosphere, skilled coaching, and adequate resources. The similarities are summarised in Table 2.

Table 2. A summary of the similarities between EPM and EPD.

Study Objectives	Similarities
Concepts and practice	Include continuous development, risk management, resource allocation, collaboration, and communication
	Support the integration of cutting-edge technology and methodologies.
	Encompass a range of procedures throughout the whole lifecycle (these procedures in EPM and EPD have comparable functions).
	Transform ideas and activities into actual results.
Risk Management and Quality Assurance	Regard BIM as valuable for assessing risks related to time, scheduling, and cost.
	Implement TQM
	Support integration of advanced methodologies and strategic planning is crucial.
Productivity Improvement and Growth	Support involvement, integration, and management of several disciplines as team members, their collaboration, and effective communication for high productivity and functioning.
	Support self-managing teams and adherence to plans.

4.2.2. Differences

The Observations were made regarding the disparities in emphasis and scope, methodologies and approaches, quality assurance practices, and goals and utility. The applicability of both strategies was found to be distinct. EPD focuses on the development or improvement of products throughout their entire lifecycle (from ideation to final production), whereas EPM facilitates the seamless execution of product development by emphasising resource planning, organisation, allocation, and administration. Similarly, EPM uses methodologies such as agile scrum, system management, and PRINCE2, while EPD optimises resources for research, prototyping, design, and testing. However, experts have examined that integrating advanced methodologies and strategic planning is crucial.

In the engineering field, another area of concern was the methods, resource allocation, and utility of EPM and EPD. The research revealed that the governance of EPM methods and resource allocation occurs on a broad scale. The EPM employs the resource allocation process to efficiently utilise a wider spectrum of resources, in contrast to the EPD, which operates on a more limited scope [43]. Also, in EPM, resource allocation uses a decentralised approach, including systems management, agile scrum, and PRINCE2 methodologies, while EPD focuses on utilising methodical processes such as project planning, work breakdown structure, and prioritisation of key tasks.

Within quality assurance contexts, the TQM model enhances product quality in both processes. To guarantee quality standards, comparatively, the EPD process uses an idea-to-launch methodology like the stage-gate system, while the EPM employs statistical quality control methods involving several methodologies, including the Six Sigma methodology. These methodologies enable the creation of engineering products with increased innovation and efficiency [8]. While both management approaches involve team management in the development, launch, and maintenance of a product, EPD's tasks do not encompass administrative aspects, which EPM oversees [2]. The overall differences are summarised in Table 3.

Table 3. A summary of the differences between EPM and EPD.

Study Objectives	EPM	EPD
Concepts and practices	Entails smooth implementation of the product development phase endeavours.	Encompasses the methodical process of designing and enhancing goods.
	Involves processes like project planning, organization, and execution.	Includes the whole process of creating, designing, and bringing a completely new product to the market.
Resource allocation	Methods and resource allocation occur on a broad scale.	Operates on a more limited scope.
	Utilise decentralised methodologies, including agile scrum, system management, and PRINCE2®.	Utilise a methodical approach, including work breakdown structure, and prioritisation of key tasks.
Risk Management and Quality Assurance	Incorporates statistical quality control methods like Six Sigma methodology, root cause analysis, and quality metrics.	Utilise an idea-to-launch methodology like the stage-gate system.
Productivity Improvement and Growth	Encompass administration.	Excludes administration.

5. Conclusions

This study investigated two fundamental engineering methods, namely EPM (Engineering Project Management) and EPD (Engineering Product Development). The study employed a systematic review and a thematic analysis method. Although both management methods are pivotal for the successful completion of engineering projects, the findings determined that EPD encompasses a wider scope than EPM. The former involves the entire process of creating, designing, and introducing a completely new product to the market, while the latter focuses on activities such as risk management, scheduling, and resource allocation to ensure project success. Analysing the methods revealed that both EPD and EPM involve a continuous

development process, risk management, resource allocation, collaboration, and communication to effectively manage projects. Nevertheless, there are differences observed in the methods, quality assurance, and utility and resource allocation. This research contributes to project management by illuminating the parallels and distinctions between the EPM and EPD, valuable to professionals aiming to build versatile skill sets. The nature of the research suggests a need for more empirical data to make it more realistic and experience-based. Furthermore, focusing on a specific industry, like construction or IT project management, can lead to more specific results.

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