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An Exploratory Study About Integrating Enterprise Engineering Change Management into Blockchain Technology

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Abstract: Heightened interest in providing transparency and security within business systems and processes has triggered a multitude of studies on the adoption of emergent technologies. Blockchain technology (BCT) has emerged to address issues of transparency, efficiency, and security in manufacturing, supply chain, enterprise, and e-commerce systems. Given the enormous success of BCT in financial applications, there is keenness to explore other application areas. This research explores the integration of BCT in enterprise systems to enhance the engineering change management (ECM) process. Employing the technology acceptance model (TAM) to assess adoption intentions from the perspective of users, two concepts were examined: perceived usefulness (PU) and perceived ease of use (PEU). A quantitative survey method collected and analysed the perception data. The findings revealed a positive perception of both usefulness and ease of use from the users in adopting a blockchain-enabled enterprise platform to support the ECM process. More detailed findings uncovered the workflow management function as an area that may require further technical exploration. These findings provide valuable insights on the benefits of blockchain in optimizing business processes and contribute to the growing literature about perceptions of integrating BCT in enterprise platforms.

Keywords: blockchain technology; enterprise integration; engineering change management; technology acceptance model

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1. Introduction

Change is inevitable in complex systems. Understanding interactions among subsystems and components within a complex system is critical not only to ascertain objective outcomes, but to maintain system integrity. There is constant need for change to resolve errors that occur in the process of system development. Furthermore, changes (adjustments) are also necessary because the design is *not 'right the first time'* [1]. Enterprise systems typify such complex systems, especially in manufacturing industries, where raw materials and components must be routed through different paths in the transformation process. Managing the engineering change process has been explored using several methods in both academic research and practice. Most of these explorations have focused on procedures, methods, and standardization efforts. Despite significant research in ECM, there is insufficient literature about leveraging emerging technologies to enhance the process. Engineering change management (ECM) in its systematic approach constitutes one such trajectory. ECM describes the process of dealing with engineering changes, consisting of the emergence, identification, and creation of solutions, assessment, implementation, and review of engineering changes [2]. ECM is essential to reduce the negative impact of a design change on product development, especially for complex products with essential roles in the national economy and society [3]. Huge financial losses, quality compromises, lengthy time to market, and damage to reputation are potential issues faced by manufacturing organizations when implementing engineering change management frameworks. Ref. [1] underscored the lack of digital continuity on an end-to-end level as one of the primary challenges faced by those undergoing an ECM process. Problematic issues consist of manual effort, discontinuity of data and processes, low degree of digitalization and complexity experienced in ECM [4]. Engineering changes, in the manufacturing context, are frequently triggered by requirement changes, design errors, supplier changes, and quality-control problems [5].

In this research, the bill of materials (BOM), a typical object in manufacturing planning and execution, will be used to assess the efficacy of integrating blockchain technology (BCT) into the ECM process. Emergent and disruptive BCT has evolved in recent years and is making inroads in other industries outside of the financial sector, where it has been utilized extensively. It has the potential to positively disrupt the manufacturing ecosystem from a change management perspective. Blockchain is a distributed ledger or database running simultaneously on many (possibly millions of) nodes that can be distributed geographically across many organizations or individuals [6]. Its capabilities are not limited to a decentralized orientation and can be extended even further by auxiliary features including distributed ledgers, immutability, consensus, and smart contracts [7]. A distributed ledger technology, using an irreversibility-of-records design, brings better traceability and can resolve important trust-related issues in organizations [8]. Hence, incorporating BCT in enterprise resource planning (ERP) systems is likely to foster the next generation of business technologies that will reshape organizations [9]. Interfacing and diverse IT platforms are becoming seamless in this technological environment and, therefore, BCT could fit into existing IT infrastructures utilizing middleware layers, plug-and-play web services, and backend software [10]. Consequently, the above-mentioned features of BCT deserve strong consideration for integration in the ECM process, especially given the vulnerability of record alterations within centralized infrastructures. Additionally, this study reviews the evolving operationalization of BCT and its integration with ERP from the perspective of improving the transparency, traceability, and security of engineering changes as well as providing opportunities for future research. To examine the potential of integration, the research employs the technology acceptance model (TAM), a prominent information systems theory that provides key factors to assess the acceptance of innovative technologies [11]. TAM is premised on the idea that technological adoption is driven by behavioural intentions and attitudes, which are preceded by the validation of two principal concepts: perceived usefulness (PU) and perceived ease of use (PEU). Deploying the TAM framework, this investigation is guided by two research questions:

1. To what extent is the integration of blockchain technology perceived to influence an ERP-driven engineering change management process?
2. To what extent do users perceive an enhanced ease of use by employing a blockchain-enabled enterprise engineering change management process?

Addressing these research questions will add to the BCT literature regarding integrating enterprise systems and introduce a new area of application in change management. Hopefully, this effort will spur both academic and practice communities to further explore and develop new techniques. The paper is structured as follows: Section 2 provides a literature review which discusses the concepts of BCT, ECM, ERP, and BOM in the context of this research, and provides a critique of the prevailing research gap. It also examines the challenges in blockchain technology-enabled enterprise ECM mechanisms. Section 3 presents the conceptual model of the research. Section 4 discusses the theoretical foundation by examining and comparing different technology acceptance models. Section 5 discusses the methodology employed in this research. Section 6 provides the data analyses and model limitations. Section 7 discusses the results in conjunction with recent research in similar areas of application, and Section 8 concludes the study and suggests future research perspectives.

2. Literature Review

This section reviews the main concepts of this study, including blockchain technology, engineering change management, and enterprise resources planning. A juxtaposition of BCT and ERP will help point out our prospects for integration. The key articles that were exploited during the review are summarized in Table 1.

Table 1. Summary of key articles.

Author and Published Year	Article Name	Key Finding
Kitsantas (2022)	Exploring Blockchain Technology and Enterprise Resource Planning System: Business and Technical Aspects, Current Problems, and Future Perspectives	Integrating blockchain technology with ERP systems can enhance data security, transparency, and efficiency, enabling decentralized operations and real-time transaction visibility.
Justinia (2019)	Blockchain Technologies: Opportunities for Solving Real-World Problems in Healthcare and Biomedical Sciences	Blockchain technology offers long-term benefits like improved cash flow, reduced transaction costs, and new trust models through distributed ledgers.
Satoshi Nakamoto (2008)	Bitcoin: A Peer-to-Peer Electronic Cash System	A system for electronic transactions without reliance on trust was proposed, utilizing a peer-to-peer network and proof of work to prevent double spending.
Tavcar and Duhovnic (2005)	Engineering change management in individual and mass production	The engineering change (EC) process should be divided into decision-making and rapid-implementation phases, with effective communication and prototype production being crucial for success.
Das et al. (2022)	A blockchain-based integrated document management framework for conception applications	The proposed blockchain-based document management system enhances security in AEC projects by ensuring irreversibility, non-repudiation, and data integrity, addressing the limitations of centralized systems.
Wilberg et al. (2015)	Using a Systemic Perspective to Support Engineering Change Management	The paper proposes a novel, systemic approach to engineering change management (ECM), emphasizing flexibility and learning from previous changes to improve efficiency.
Jokinen et al. (2017)	Engineering Change Management Data Analysis from the Perspective of Information Quality	The quality of an engineering change request (ECR) is crucial for fast processing, with high-quality requests leading to quicker changes, while poor-quality requests cause delays.

Table 1. *Cont.*

Author and Published Year	Article Name	Key Finding
Abd Elmonem et al. (2016)	Benefits and challenges of cloud ERP systems—A systematic literature review	The study identified key benefits of cloud ERP systems, including lower costs, scalability, fast implementation, and improved accessibility.
Mishra et al. (2022)	Cyber Security Application in ERP Implementation	Organizations must prioritize security measures and employee training to safeguard their ERP deployments against cyberattacks.
Mishra (2020)	Evolution of ERP Cybersecurity	It is necessary to take the required precautions to ensure that ERP systems are secure.
Gunjal (2019)	Enterprise resource planning (ERP) as a change management tool	The study identifies 10 critical success factors (CSFs) for effective change management in ERP implementation, including clear strategic goals, top management commitment, excellent project management, and organizational change management.
Huang et al. (2019)	Critical Success Factors in Implementing Enterprise Resource Planning Systems for Sustainable Corporations	The study identifies 41 critical success factors (CSFs) across five dimensions for successful ERP implementation, emphasizing that ERP systems enhance internal control reliability, improving brand image and sustainability.
Faccia and Petratos (2021)	Blockchain, Enterprise Resource Planning (ERP) and Accounting Information Systems (AIS): Research on e-Procurement and System Integration	The study finds that blockchain can improve e-procurement processes, facilitating the integration of ERP and AIS systems.
Kurniadi and Ryu (2021)	Development of Multi-Disciplinary Green-BOM to Maintain Sustainability in Reconfigurable Manufacturing Systems	The study introduces a method for grouping parts in reconfigurable manufacturing systems (RMS) using Green-BOM to enhance sustainability and efficiency.
Khan et al. (2021)	Blockchain smart contracts: Applications, challenges, and future trends	Smart contracts, with their decentralization, auto-enforcement, and verifiability, have the potential to transform traditional industries by enabling peer-to-peer transactions without a central authority.
Hristova et al. (2024)	Analysis of Data Sharing Systems in the Context of Industry 4.0 via Blockchain in 5G Mobile Networks	Complexity and cost of blockchain, the need for detailed pre-implementation research, and the critical decisions required before proceeding with such integration.
Imane et al. (2024)	Towards Blockchain-Integrated Enterprise Resource Planning: A Pre-Implementation Guide	Challenges of integration, such as the immaturity of blockchain in certain applications, the need for interoperability, and the complexities involved in integrating centralized systems with blockchain

2.1. Blockchain Technology

Digitalization in recent years has been the backbone of several innovations. BCT typifies one such innovation in recent times, with the financial sector being its original area of implementation. It can enhance security and assist in inducing trust in a trust-less ecosystem. Remarkably, it does this without a central authority for financial transactions such as banks and financial institutions [9]. A blockchain is a distributed system of records that is shared between participants, records all transactions carried out by any member, and ensures all participants have their own copy of the ledger through replication [12]. Both networking and database attributes are captured in this definition and are critical in understanding how technology works. Typically, blocks created at several echelons of a transactional trail are linked together within a distributed ledger, which forms the basis of blockchain. A cryptographic hash that embeds all preceding transactions in the chain is appended to subsequent blocks in the network. Figure 1 below provides a conceptual depiction of how data blocks form a blockchain.

In 2008, Satoshi Nakamoto published a paper on Bitcoin, entitled "A Peer-to-Peer Electronic Cash System". That paper described an electronic payment system based on cryptography and introduced the concept of decentralization in a transactional network without reliance on a third-party source for validation. Organizations have depended on centralized databases typical to enterprise systems. Irrespective of several advantages presented by centralized systems, they remain vulnerable in terms of security and trust and could easily be targeted by hackers. On the other hand, the decentralized model qualifies BCT as a tamper-proof technology. Figure 2 below provides a conceptual depiction of centralized, decentralized, and distributed frameworks.

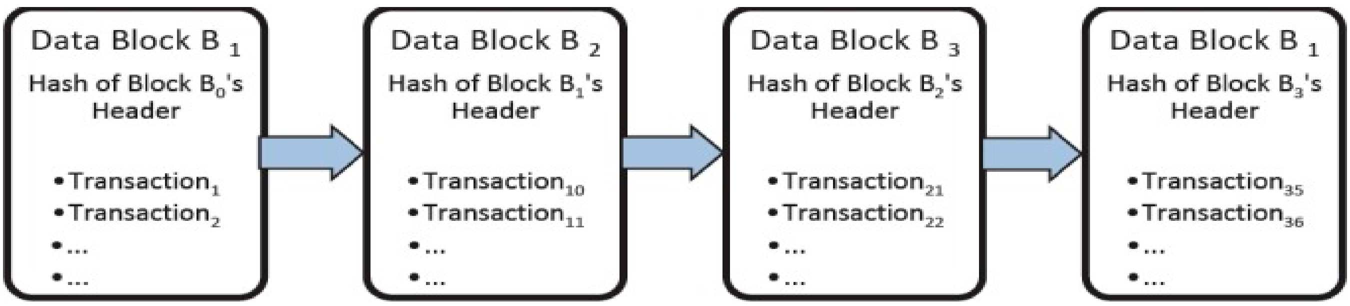


Figure 1. How data blocks form a blockchain (Adapted from [12]).

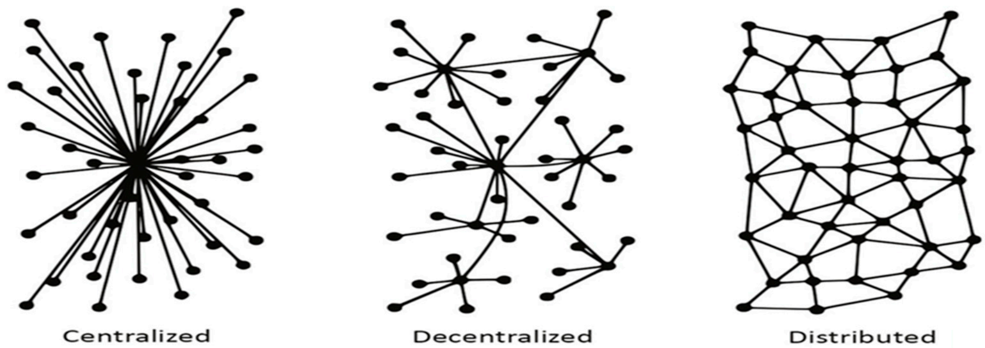


Figure 2. Centralized, decentralized, and distributed frameworks (Adapted from [13]).

BCT also operates in a flexible landscape that allows for three types of network configurations: public, private, and federated networks. While participants can anonymously join a public network, both private and federated networks require permission. A blockchain-driven network can be applied in the context of managing engineering changes. Irrespective of the landscape adopted during implementation, organizations can be assured that data pertaining to critical engineering changes within the enterprise remain uncompromised. BCT application has been utilized outside the financial arena, in areas of supply chain management, and has the potential to supplement engineering change management.

2.2. Engineering Change Management

At a superficial level, the management of changes connotes a continuous process of monitoring and updating milestones of an event, project, product, or service package of any size or type. Moreover, there is often a deficit in the amount of attention that is placed on the subject, especially when it comes to engineering changes (ECs). According to Ref. [14], the key contributors to long EC lead times are complex approval process, snowballing changes, scarce capacity, and organizational issues. In product development, it is critical to keep product growth on track as well as maintain the integrity of product information. Thus, the management of engineering changes is crucial and should be supported by robust scientific approaches. Nevertheless, electronically stored documents are susceptible to alteration and loss, which can result in legal issues during a project [15]. Many studies have attempted to investigate ECM from varied perspectives. An extant reductionist approach is often adopted by researchers, stimulating the need for a more systemic approach. According to Ref. [16], ECM seeks to anticipate and identify possible changes in the system, plan preventive measures, and coordinate the entire change process. This ambient definition suggests other avenues to improve the change management process within systems, especially in the current dispensation of disruptive technologies and hence the need to supplement BCT in the enterprise framework. According to Ref. [17], ECM is very prominent in product data management, prompting many engineering change requests (ECR), especially in manufacturing companies. Manufacturers must swiftly attend to ECs in response to product modification and substitution, market demand, safety concerns, regulatory requirements, and other concerns. ECM is a systematic process which begins with the identification of the intended change. The identification phase is accompanied by the creation of an ECR, which triggers a series of review and approval processes. An engineering change order is usually generated once the initiated request is finally approved. Upon approval, the intended changes are executed, and the entire process is monitored until final closure. Figure 3 below shows the generic steps involved in an ECM initiative.

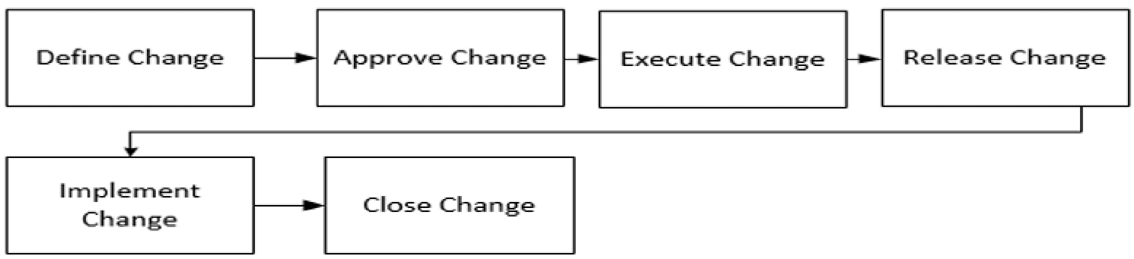


Figure 3. Generic steps of the ECM process (Adapted from [18]).

2.3. Enterprise Resource Planning

The enterprise resource planning (ERP) concept seeks to integrate business processes from several functional areas within an organization for purposes of planning, executing, and controlling activities that are crucial to achieving strategic goals. ERP is an extension of material requirement planning (MRP) and manufacturing resource planning (MRP II) concepts, which are predominantly inventory management and manufacturing based. The antecedent of ERP transcends the basic objectives of stock requirement calculations to support production through the optimization of capacity requirements in manufacturing. The idea behind ERP is to optimize the use of a business's internal resources, and it emphasizes the integration of cross-system functions, cross-organizational departments, and cross-geographical regions [19]. The ERP framework, therefore, suggests a centralized model of operation, which is typical in the SAP and Oracle application packages. A depiction of an ERP system consists of modules that represent business functions such as finance and controlling, sales and distribution, material management, human resource management, and plant maintenance—all sharing a centralized database. The centralized architecture ensures that data are accessible in real time within the entire system. Figure 4 below shows an ERP integration diagram.

Figure 4. ERP integration diagram (Adapted from [20]).

Although ERP has been extensively researched, its implementation challenges across organizations and industries remain critical. The advent of Industry 4.0 has brought about novel ideas to incorporate new technologies into the existing ERP framework. These advances have created seamless integration opportunities such as cloud computing, cybersecurity, and blockchain technology. Cloud computing, for instance, is a computing environment which provides availability, scalability, and flexibility of computer resources at a different level of abstraction with low running costs [21]. Cloud computing has dramatically reduced the limitations presented by on-premises ERP and, therefore, increased real-time data visibility across geographical zones and supply chain partners. Refs. [22,23] emphasized the advisability of approaching ERP implementation with circumspection, especially where vulnerabilities to cyberattacks are present. Ref. [9] contended that integrating current ERP with BCT could improve optimization, increase security in transactions, enhance transparency control, and create trust in a trust-less environment. Moreover, ERP is one of the most popular change management tools that has been used by companies across the globe to integrate and rationalize their processes [24].

2.4. Comparing ERP and BCT

This study relies on a thorough understanding of the differences between enterprise resource planning and blockchain technology. In theory, they both have significant commonalities. They both are characterised by a systematic approach in pursuit of a systemic outcome. Furthermore, it is tempting to assume that BCT might eventually replace ERP. However, the fundamental differences of both technologies in terms of characteristics and objectives should not be overlooked. ERP is driven by a centralized architecture, whereas BCT adopts a decentralized orientation. As summarized by Ref. [25], data integration, centralized data control, integration of business processes, standardization of business operations, real-time analysis, and evaluation of decision-making programs are core objectives and expectations of an ERP implementation. On the other hand, blockchain and distributed ledger technologies enable the internet of value, which is based on five "ingredients": network, algorithms, distributed ledgers, transfers, and assets [26]. BCT applications have emerged with the primary objective to record and disseminate digital information through a distributed network, while assuring transparency, immutability, and security. Ref. [27] highlighted the complexity and cost of blockchain, the need for detailed pre-implementation research, and the critical decisions required before proceeding with such integration. The article further addressed issues like data interoperability, the necessity for synchronization between blockchain and ERP systems, and the various technical and managerial decisions that need to be made during the pre-implementation phase. Ref. [28] addressed the challenges of combining ERP and blockchain technologies, such as the immaturity of blockchain in certain applications, the need for interoperability, and the complexities involved in integrating centralized systems with blockchain. Table 2 shows the main differences between ERP and BCT.

Table 2. Main differences between ERP and BCT.

Enterprise Resource Planning (ERP)	Blockchain Technology (BCT)
Centralized model	Decentralized model
Modular oriented	Block based
Rational transactional database	Linear transactional database
Uses workflows and programmable algorithm	Uses automated smart contracts
Data alteration possible	Data immutability
Limited transparency	Transparency
Scalable	Limited scalability potential
Does not allow incentivization	Allows incentivization
High maintenance cost	Low maintenance cost

2.5. Integrating and Deploying BCT in ECM Process

Integrating BCT in the ECM process can be envisaged in different ways. An enterprise might process several objects whose changes are monitored on a continuous basis through ECM. These objects include critical parts, equipment, technical drawings, and bills of materials (BOM). For reasons of clarity and simplicity, this study utilized the bill of materials (BOM) as the main object under investigation. In discrete manufacturing, the BOM is a listing of parts, components, raw materials, and sub-assemblies needed to create a finished good or product. Each combination of parts serves the desired functions of a complete product [29]. The structure of the BOM varies from one product to another. More complicated products such as automobiles and aircrafts present complex BOM structures. Figure 5 below shows single-level and multi-level BOM structures.

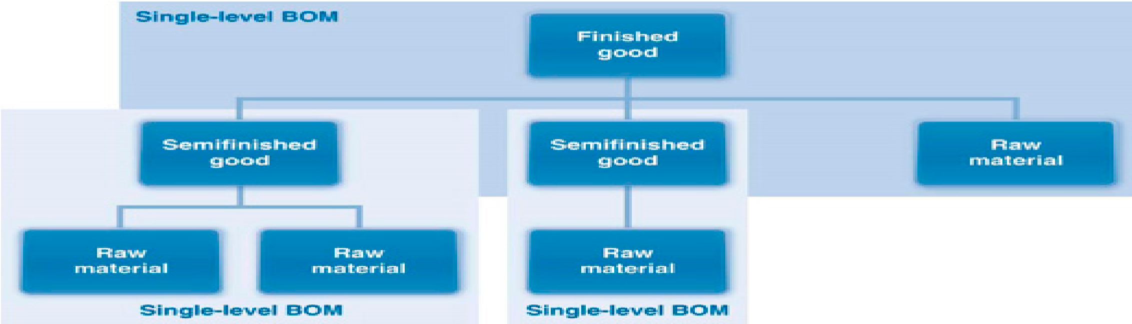
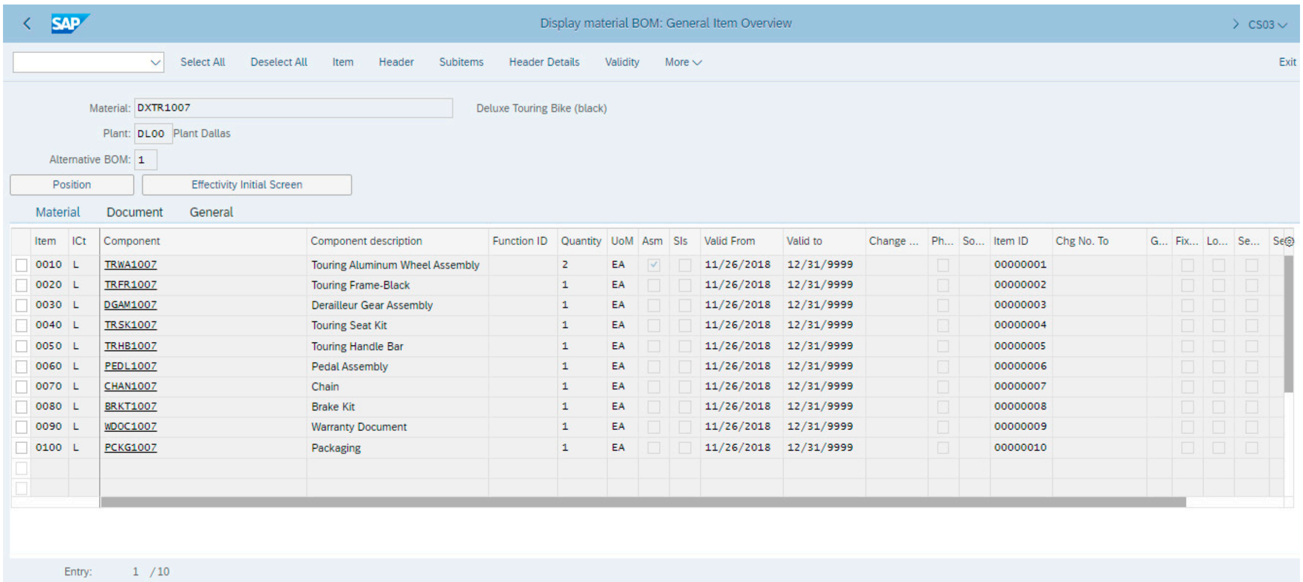


Figure 5. Single-level and multi-level BOM structures (Adapted from [30]).

The BOM is central to production planning and execution as it further details the quantities and other pertinent data and delineates the relationship between the parent item (finished good) and its components. In concert with the BOM, recipes and ingredients are often used in process manufacturing. Figure 6 below shows a detailed BOM list in an SAP ERP application.



Item	ICt	Component	Component description	Function ID	Quantity	UoM	Asm	Sls	Valid From	Valid to	Change ...	Ph...	So...	Item ID	Chg No. To	G...	Fix...	Lo...	Se...	Se
0010	L	TRWA1007	Touring Aluminum Wheel Assembly		2	EA	✓		11/26/2018	12/31/9999				00000001						
0020	L	TRFR1007	Touring Frame-Black		1	EA			11/26/2018	12/31/9999				00000002						
0030	L	DGAM1007	Derailleur Gear Assembly		1	EA			11/26/2018	12/31/9999				00000003						
0040	L	TRSK1007	Touring Seat Kit		1	EA			11/26/2018	12/31/9999				00000004						
0050	L	TRHB1007	Touring Handle Bar		1	EA			11/26/2018	12/31/9999				00000005						
0060	L	PEDL1007	Pedal Assembly		1	EA			11/26/2018	12/31/9999				00000006						
0070	L	CHAN1007	Chain		1	EA			11/26/2018	12/31/9999				00000007						
0080	L	BRKT1007	Brake Kit		1	EA			11/26/2018	12/31/9999				00000008						
0090	L	WDOC1007	Warranty Document		1	EA			11/26/2018	12/31/9999				00000009						
0100	L	PCKG1007	Packaging		1	EA			11/26/2018	12/31/9999				00000010						

Figure 6. A detailed BOM list in SAP ERP system. (Adapted from SAP ERP Application).

A BOM plays an important role in determining inventory requirements as well as scheduling production activities during manufacturing. An inaccurate modification of the BOM could have severe consequences for the entire organization. The consequences could be more detrimental in organizations that rely on variant configuration and integrated e-commerce technology to sell and distribute products. Ref. [29] developed a BOM for the sustainable reconfiguration of manufacturing systems, in which the need for manufacturers to holistically plan and implement reconfigurations was emphasized. The changeability of manufacturing systems caused by rapidly changing market demands and product variations are important considerations for global companies [29]. BCT has the potential to enhance change management process for very complex BOMs. Its distributive framework could advance the status quo by rendering the centralized framework accessible across multiple platforms. This integration enhances trust, especially as data sharing of engineering changes would be optimized by the trusted source. The security features in BCT ensures an environment in which changes in the BOM life cycle are traceable, trackable, and immutable. Inputs from authorized personnel remain controlled, since they are verified using digital signatures supported by cryptography. This further excludes the possibility of tampering with stored engineering change records during the life cycle of the BOM object. Furthermore, smart contracts have emerged as a new promising solution for developing fully decentralized applications without involving a trusted third party [31], prompting an increase in flexibility in the change management process.

3. Conceptual Model

A conceptual framework for integrating BCT in the ECM process using a BOM minimizes ambiguity and provides a better understanding of the phenomenon. The conceptual framework creates reality [32]. As previously captured in Figure 3, the generic ECM process is comprised of the *define*, *approve*, *execute*, *release*, *implement*, and *close* phases. The conceptual model in Figure 7 details the phases of the ECM process, highlighting how each phase would be integrated with BCT and ERP systems:

- **Define Change:**

Description: The initial step involves a detailed description of the change, such as part substitution, which is initiated in the ERP system by the user (requestor). A unique change number is created, and a workflow for the approval process is triggered.

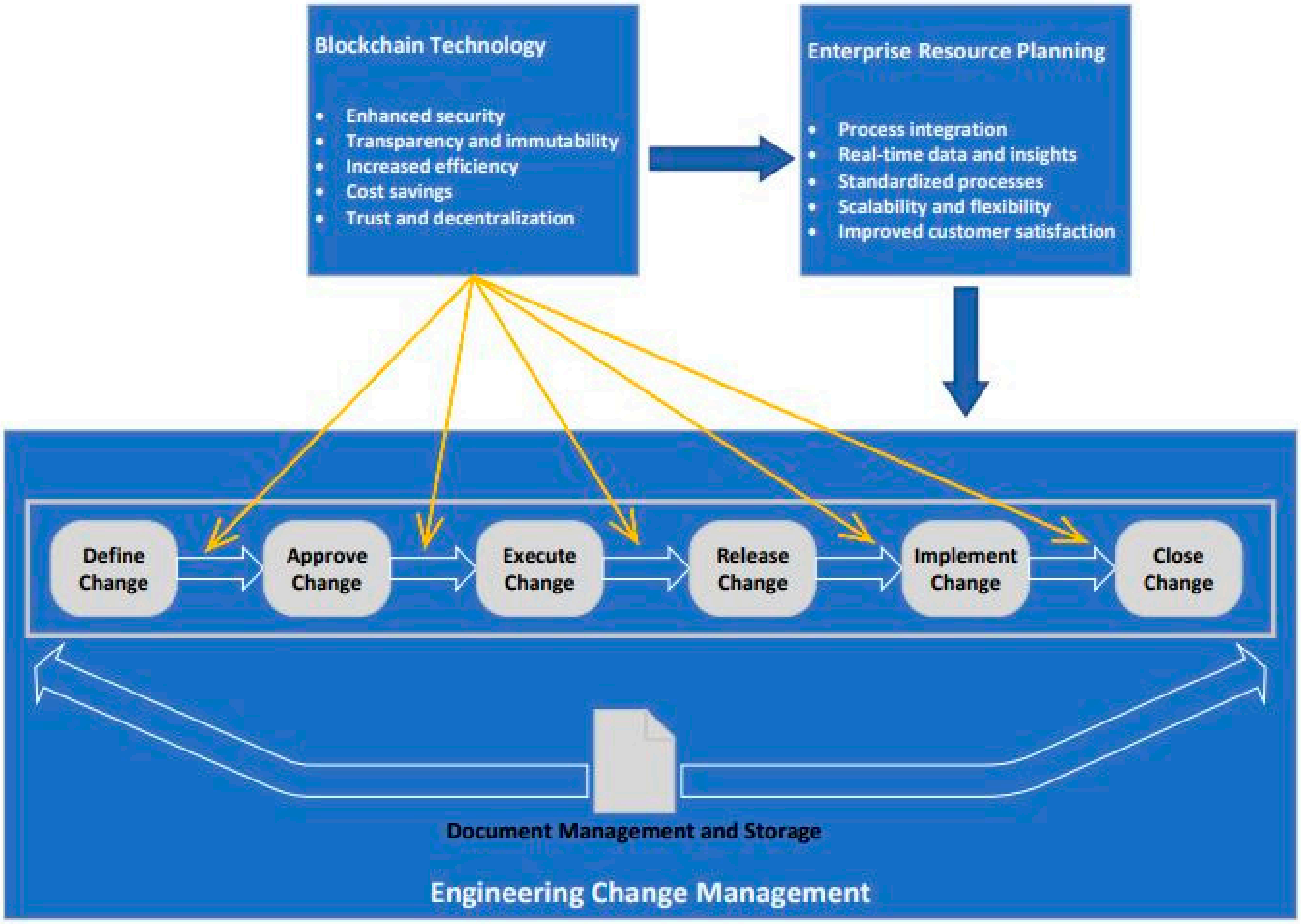


Figure 7. A conceptual model of a blockchain-enabled ECM process.

Relevance: This phase sets the stage for the change management process, ensuring that all relevant details are captured and that the change is tracked from the outset.

- **Approve Change:**

Description: The proposed change is reviewed by a team of stakeholders. Based on their assessment, the change is either approved or denied. Once a decision is made, a workflow notification is triggered to inform relevant parties.

Relevance: Approval is a critical control point that ensures only necessary and well-considered changes are implemented, maintaining the integrity of the product or process.

- **Execute Change:**

Description: Upon approval, the part substitution or other change is executed within the ERP system. This phase includes making the necessary adjustments to the product or process documentation and updating the BOM (bill of materials).

Relevance: Execution ensures that the approved changes are accurately reflected in the system, paving the way for subsequent implementation.

- **Release Change:**

Description: The change is planned and scheduled for implementation based on the effective date. A programmed algorithm within the ERP system manages this scheduling to ensure that changes are implemented at the right time.

Relevance: Proper planning and scheduling are crucial for minimizing disruption to ongoing operations and ensuring that changes are implemented smoothly.

- **Implement Change:**

Description: The change is implemented according to the scheduled plan. Once implemented, a workflow notification is triggered to update all stakeholders.

Relevance: This phase is where the change becomes operational, affecting the product or process as intended. Effective implementation is key to realizing the benefits of the change.

- **Close Change:**

Description: After implementation, the change management team reviews the changes to ensure they have been carried out correctly. Once satisfied, the change is officially closed and a final workflow notification is triggered.

Relevance: Closing the change formalizes the end of the change process and ensures that all aspects of the change have been correctly implemented and documented.

4. Theoretical Framework

Existing theories are utilized to establish logical connections of the concepts under investigation. Experimenting with the integration of BCT can be tricky. However, given that the technology has been successful in some areas of application, an opportunity presents itself to inquire further by way of user perception. The assumption of an in-depth understanding of all associated technologies and platforms must be considered. According to Ref. [33], users' willingness is a critical factor to determine the successful implementation and utilization of a technology. Among several models that have been used in technology innovation and adoption, the technology acceptance model (TAM) stands out in the research.

4.1. Technology Acceptance Model

TAM is rooted in the fields of sociology and psychology. The model is very popular in the usability arena and has become the most frequently used model in various research studies [34]. TAM traces its origin as far back as 1985, when Fred Davis in his dissertation investigated the key drivers of the adoption of a new technology. He hypothesized that the attitude of a user toward a system was a major determinant of whether the user would use or reject the system [35]. TAM is premised on the idea that technological adoption is driven by behavioural intentions and attitudes, which are preceded by the validation of two principal concepts: perceived usefulness (PU) and perceived ease of use (PEU). Perceived usefulness is defined as the prospective user's subjective probability that using a specific application system will increase his or her job performance [36]. On the other hand, perceived ease of use is the degree to which the prospective user expects the target system to be free of effort. The relationship between the explained concepts that make up the original version of TAM is captured in Figure 8.

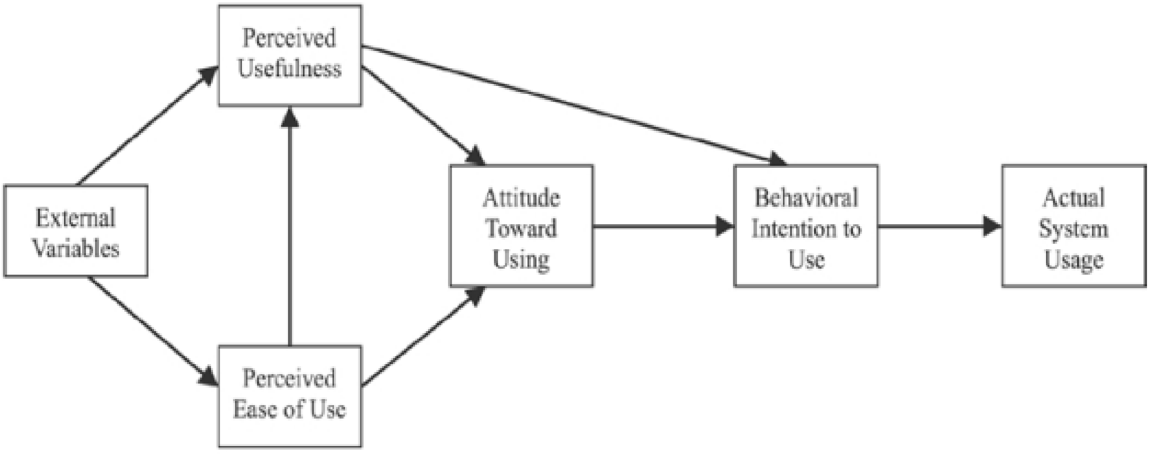


Figure 8. Technology acceptance model (Adapted from [11]).

4.2. Unified Theory of Acceptance and Use of Technology

The unified theory of acceptance and use of technology (UTAUT) is a comprehensive model that integrates and extends various existing technology acceptance theories. Proposed in Ref. [37], UTAUT aims to provide a unified framework for understanding users' acceptance and usage of technology. The model consists of four key concepts: performance expectancy (PE), effort expectancy (EE), social influence (SI), and facilitating conditions (FC). PE refers to the degree to which individuals believe that using the technology will enhance their performance or productivity, while EE relates to the perceived ease of use. SI considers the influence of social factors on technology acceptance, and FC encompasses the organizational and technical support provided for technology use. Additionally, UTAUT incorporates moderating factors such as gender, age, experience, and voluntariness of use. According to UTAUT, these concepts directly influence users' behavioural intentions to use the technology, which, in turn, affects their actual technology usage behaviour. The model has been widely utilized in information systems and technology acceptance research to understand and predict technology adoption and usage behaviours.

4.3. Theory of Reasoned Action

The theory of reasoned action (TRA) is a psychological theory proposed in Ref. [38]. It suggests that an individual's behaviour is determined by their intentions, which are influenced by two key factors: attitudes and subjective norms. Attitudes refer to an individual's evaluation of behaviour, while subjective norms represent social pressure and the expectations of others. According to TRA, individuals are more likely to engage in a behaviour if they have a positive attitude towards it and perceive social approval for it.

4.4. Theory of Planned Behaviour

The theory of planned behaviour (TPB), developed in Ref. [39], is a widely recognized social psychological theory that aims to explain and predict human behaviours. The theory suggests that behavioural intentions are influenced by three key factors: attitudes toward the behaviour, subjective norms, and perceived behavioural control. Attitudes refer to an individual's evaluation of the behaviour, subjective norms encompass social pressures and expectations, and perceived behavioural control reflects one's perception of one's ability to perform the behaviour. TPB posits that these factors collectively shape an individual's intention to engage in a behaviour, which in turn influences actual behaviour.

4.5. Model Comparison

Among the four theories/models of technology acceptance, namely TRA, TPB, UTAUT, and TAM, TAM stands out as the most favourable choice due to its simplicity, widespread adoption, and effectiveness in explaining technology acceptance. Compared to TRA, TAM offers a more focused approach by emphasizing the crucial determinants of technology acceptance, which are perceived usefulness and perceived ease of use. TAM provides a straightforward and easy-to-understand framework, enabling researchers to quickly grasp the underlying factors influencing individuals' attitudes and behaviours towards technology. Some of these attributes are accentuated in the literature. Ref. [40] utilized TAM to assess stakeholders' acceptance of blockchain in corporate governance to resolve issues of financial record keeping. Ref. [41] also deployed the theoretical framework of TAM to investigate the possibility of adopting BCT using machine learning methods. On the other hand, the TRA model has some limitations, including a significant risk of confusion of attitudes and norms, since attitudes can often be reframed as norms and vice versa [42]. The second limitation is the assumption that when someone forms an intention to act, they will be free to act without limitation [42]. TPB attempts to address some of TRA's limitations but still falls short in certain respects. TPB has been the explicit theoretical basis for many studies over various contextual settings. Therefore, TPB should provide a more complete understanding of technology usage [43]. But Ref. [11] explained that social norm scales have a very poor psychometric standpoint and may not exert any influence on BI, especially when social influence (SI) applications are personal and individual usage is voluntary. UTAUT, although a comprehensive model, encompasses a broader range of factors and incorporates moderating variables. While this expansiveness contributes to its holistic nature, it may also lead to complexity and challenges in practical application and customization to specific contexts. In contrast, TAM strikes a balance between simplicity and effectiveness. It has been widely adopted in research studies and has demonstrated its capability to explain and predict individual behaviours across various technology domains and user groups. TAM's straightforward nature and proven track record make it an ideal choice for understanding and predicting technology acceptance, while still providing valuable insights into users' perceptions and behaviours. Ref. [44] explored how TAM can be used as a predictive tool for user acceptance when implementing a new technology, such as automated inspection equipment, in manufacturing settings. It addressed the challenges of change management and investigated the relationship between perceived usefulness, perceived ease of use, and their impact on successful technology implementation. Key limitations in Ref. [44] included an inadequate sample size, which weakened the statistical correlations. Moreover, there is a need for further validation of TAM in non-IT fields like manufacturing as well as the model's limited focus on user acceptance. Nevertheless, it overlooks the broader complexities of change management, such as organizational culture and human factors.

5. Research Methodology

This section outlines the research hypotheses, methods, instrumentation, and subjects.

5.1. Research Hypotheses

The research questions are restated below.

RQ 1: To what extent is the integration of blockchain technology perceived to positively influence an ERP-driven engineering change management process?

RQ 2: To what extent do users perceive the ease of use of a blockchain-enabled enterprise engineering change management process?

RQ 1 is aimed at addressing the perceived usefulness (PU) concept, meanwhile RQ 2 addresses the perceived ease of use (PEU) concept, in accordance with the TAM framework. To address the research questions in the backdrop of the theoretical foundation, two testable hypotheses are crafted as shown below.

H1: *Integration of blockchain technology in ERP will positively impact the engineering change management process.*

H2: *A blockchain-technology-driven ERP system will ease usability in the engineering change management process*.

5.2. Methods

A quantitative research method is appropriate to explore possible associations among variables generating from the research questions under investigation. The main elements considered in the method are the survey instrument, the participants, and the statistical tools for the analyses. To properly address the questions in this research, the survey approach is best in acquiring information from professionals who are technically savvy in the relevant functional and application areas. An exploratory exercise ensued, which included reviewing and comprehending the existing literature and research trends in the investigated environment [45]. Iterative assessments of suggestive survey items throughout the literature were conducted to ensure proper alignment with both PU and PEU concepts. The process produced a survey questionnaire comprising survey items which were carefully adapted to the underlying theme. The survey questionnaire comprised 18 questions that addressed the demographics of respondents as well as both PU and PEU concepts. The first six questions solicited general information, which is important in descriptive analytics. An interplay of the demographics and critical factors of associated systems and technologies is imperative. The next six questions directly addressed the PU concept, forming the basis for answering RQ 1. Meanwhile, the last six questions addressed the PEU concept, pertaining to RQ 2. These 12 questions required the respondents to rate their level of perception on a 7-point Likert scale, which ranged from strongly disagree to strongly agree. Table 3 below shows a summary of the questionnaire structure.

Table 3. Summary of the questionnaire structure.

Item	Question/Statement	Concept
1	In which industry does your company operate?	General
2	In which department are you currently working?	General
3	How much experience do you have of working with enterprise resource planning (ERP)?	General
4	Are you currently using any form of engineering change management (ECM) process in your organization?	General
5	How much experience do you have of working with engineering change management (ECM)?	General

Table 3. *Cont.*

Item	Question/Statement	Concept
6	How acquainted are you with blockchain technology?	General
7	A blockchain-enabled ECM process in ERP will make your job more efficient	PU
8	A blockchain-enabled ECM process in ERP will increase your productivity at work	PU
9	A blockchain-enabled ECM process in ERP will improve the accuracy and reliability of data	PU
10	A blockchain-enabled ECM process in ERP will reduce inconsistencies in managing changes within your organization	PU
11	A blockchain-enabled ECM process in ERP will enhance the transparency of changes	PU
12	A blockchain-enabled ECM process in ERP will enhance the traceability of changes	PU
13	A blockchain-enabled ECM process in ERP will improve the timeliness and responsiveness in managing changes	PEU
14	A blockchain-enabled ECM process in ERP will entail a short learning curve	PEU
15	A blockchain-enabled ECM process in ERP will significantly simplify the change management process	PEU
16	Incorporating a blockchain-enabled ECM process into your current ERP workflow will be seamless	PEU
17	A blockchain-enabled ECM process in ERP will substantially decrease the time and effort required for managing changes	PEU
18	Overall user experience in a blockchain-enabled ECM environment will be adequate	PEU

The study participants were selected from a pool of professionals who are technically savvy in areas of emerging information technologies, enterprise systems, and change management. A targeted population of knowledgeable professionals was imperative because unexperienced users might not have enough knowledge about blockchain and its applications when answering the survey questionnaire, thus affecting the validity and reliability of our study [46]. The selection process was predicated on convenience and accessibility. The study utilized a convenience sampling method due to the specialized nature of the target population. Convenience sampling was chosen because of the difficulty in accessing a broad and representative sample of professionals with the requisite knowledge of blockchain technology and ERP systems. Despite potential biases inherent in convenience sampling, efforts were made to ensure diversity in the sample by recruiting participants from various professional associations, including ASCM Inland Empire, America's SAP Users' Group (ASUG), and selected LinkedIn professional groups. A total of 103 responses were returned out of 341 questionnaires. Out of the 103 responses, 18 were incomplete and had missing values, so were removed in data cleaning. Therefore, the final number came to 85. This resulted in a response rate of 30.20%, which is considered adequate, given the embryonic and evolving nature of blockchain technology research. According to Ref. [47], studies on the topic of blockchain technology have experienced low response rates, especially since research in the area has only recently begun to emerge. Ref. [48] only achieved a response rate of 6% in a blockchain study, notwithstanding the fact that a leading market research firm had been utilized to recruit US professionals. The questionnaire was deployed using

Qualtrics on the 24 October 2023 for a three-month period. During this period, participants received reminders via email and LinkedIn messages to encourage participation. Informed consent was obtained from all participants before they began the survey, ensuring they were aware of the purpose of the research, their rights as participants, and how their data would be used. The survey was designed to be anonymous, and no personally identifiable information was collected. Data collected from Qualtrics were downloaded into both the Power BI analytical tool and R statistical software for analysis. The data cleaning process was meticulously conducted to ensure the accuracy and reliability of the dataset before analysis. After the removal of unnecessary columns and the filtering out of incomplete responses, the remaining columns were renamed with more descriptive and meaningful labels. For example, columns initially labelled with generic Qualtrics identifiers were renamed to reflect the corresponding survey questions, such as "Q7 A blockchain-enabled ECM process in ERP will make your job more efficient" to "X7.PU.DEPVAR". Descriptive analyses were carried out in Power BI due to its prominence in data visualization, while subsequent analyses, including reliability analysis, correlation analysis, a Shapiro–Wilks normality test, a test for linearity/monotonicity, and logistics regression analysis, to test the research hypotheses were carried out in R statistical software.

6. Analysis and Results

This section details the analyses carried out in this research alongside the results. It is divided into four subsections. The first one outlines the survey instrument validity and provides the reliability analysis using Cronbach's alpha for both the PU and PEU concepts, including a correlation analysis. Subsequently, the descriptive analyses are presented, followed by the hypothesis testing. The last subsection addresses the model limitations.

6.1. Instrument Validity and Reliability

A survey instrument must be capable of measuring what it is intended to measure to ascertain its validity. Prior to developing the final instrument, a small-scale deployment was implemented to solicit feedback from a group of experienced professionals. Comments and suggestions raised in the pilot were scrutinized and served as a basis for improving and actualizing the final draft. This would ensure that the questionnaire addressed the research questions in a meaningful manner. Nonetheless, the propensity of the instrument to measure consistently must also be ascertained through reliability analysis. The reliability analysis was achieved by evaluating the internal consistency of survey items within each concept using Cronbach's alpha. This is significant, since the coefficient alpha is useful once the existence of a single factor or concept has been determined [49]. Internal consistency describes the extent to which all the items in a test measure the same concept, and hence it is connected to the inter-relatedness of the items within the test [50]. Typically, a Cronbach's alpha or reliability coefficient alpha of 0.70 or higher is acceptable in most social science studies. In this research, the internal consistency analysis was conducted separately for the two concepts. Survey items 7 through 12 in Table 3 were evaluated in terms of the PU concept, whereas survey items 13 through 18 pertained to the PEU concept. Table 4 shows the results of the reliability analysis (Cronbach's alpha).

Table 4. Results of reliability analysis.

Concept	Cronbach's Alpha
PU	0.935
PEU	0.815

The results in Table 4 reveal an acceptable level of internal consistency of the instrument. The Cronbach's alpha of 0.935 and 0.815 for PU and PEU, respectively, are statistically significant. Furthermore, correlation analysis performed separately for both concepts also revealed statistically significant relationships ($p < 0.05$). Tables 5 and 6 show the results of the correlation analysis performed in R statistical software.

Table 5. Results of correlation analysis for PU concept.

	X7.PU.DEPVAR	X8.PU.DEPVAR	X9.PU	X10.PU	X11.PU	X12.PU
X7.PU.DEPVAR	1					
X8.PU.DEPVAR	0.8170 **	1				
X9.PU	0.7194 **	0.7447 **	1			
X10.PU	0.5611 **	0.5844 **	0.7367 **	1		
X11.PU	0.6297 **	0.6901 **	0.8038 **	0.7218 **	1	
X12.PU	0.6605 **	0.7218 **	0.7791 **	0.6866 **	0.9333 **	1

** Correlation signif. @ 0.01 level (2-tailed).

Table 6. Results of correlation analysis for PEU concept.

	X13.PEU	X14.PEU	X15.PEU	X16.PEU	X17.PEU	X18.PEU.DEPVAR
X13.PEU	1					
X14.PEU	0.0819 **	1				
X15.PEU	0.4427 **	0.3962 **	1			
X16.PEU	0.2064 **	0.4630 **	0.3712 **	1		
X17.PEU	0.6051 **	0.3261 **	0.6671 **	0.4231 **	1	
X18.PEU.DEPVAR	0.3222 **	0.3883 **	0.4551 **	0.5253 **	0.6521 **	1

** Correlation signif. @ 0.01 level (2-tailed).

6.2. Descriptive Analysis

General information was solicited in the survey instrument to provide a respondent profile. Demographic data of interest included industry, department, experience with ERP and ECM as well as acquaintance with BCT. A preponderance of the respondents stemmed from the manufacturing (33.80%) and education (19.72%) sectors. Intriguingly, the information technology industry also contributed up to 14.08% of the respondents. From a departmental perspective, operations and information technology contributed 42.35% and 24.70%, respectively. These outcomes signified a meaningful participation in the survey exercise. They also resonated with the divergent technological application areas involved in the research. Figure 9 below shows a visual representation of participation based on industry and department.

Workplace experience of using ERP and ECM were very crucial factors to consider. The results revealed that 74.11% of the respondents had over four years of experience working with ERP, which signified adequate representation of individuals with reasonable experience regarding the dynamics of ERP. Conversely, experience with ECM was lagging. Respondents with less than three years of experience working with ECM accounted for 50.59%, even though 63.53% of overall participants indicated currently using ECM in their enterprise landscape. Figure 10 shows a graphical representation of participation based on experience with ERP and ECM.

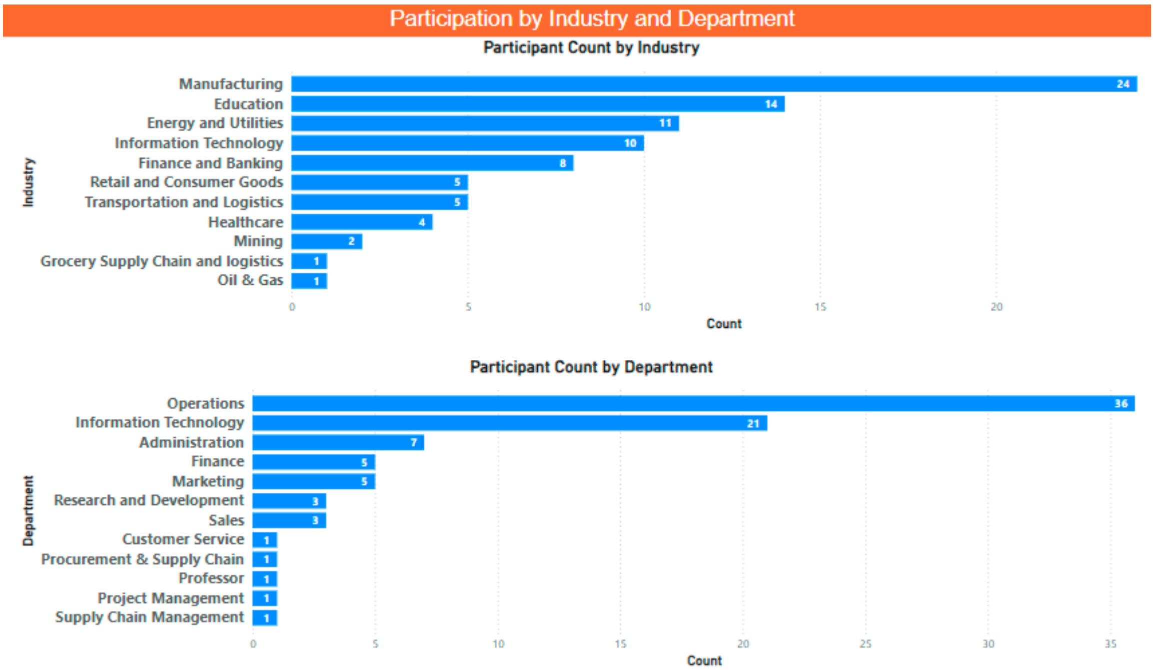


Figure 9. Detailed results of industry and department participation.

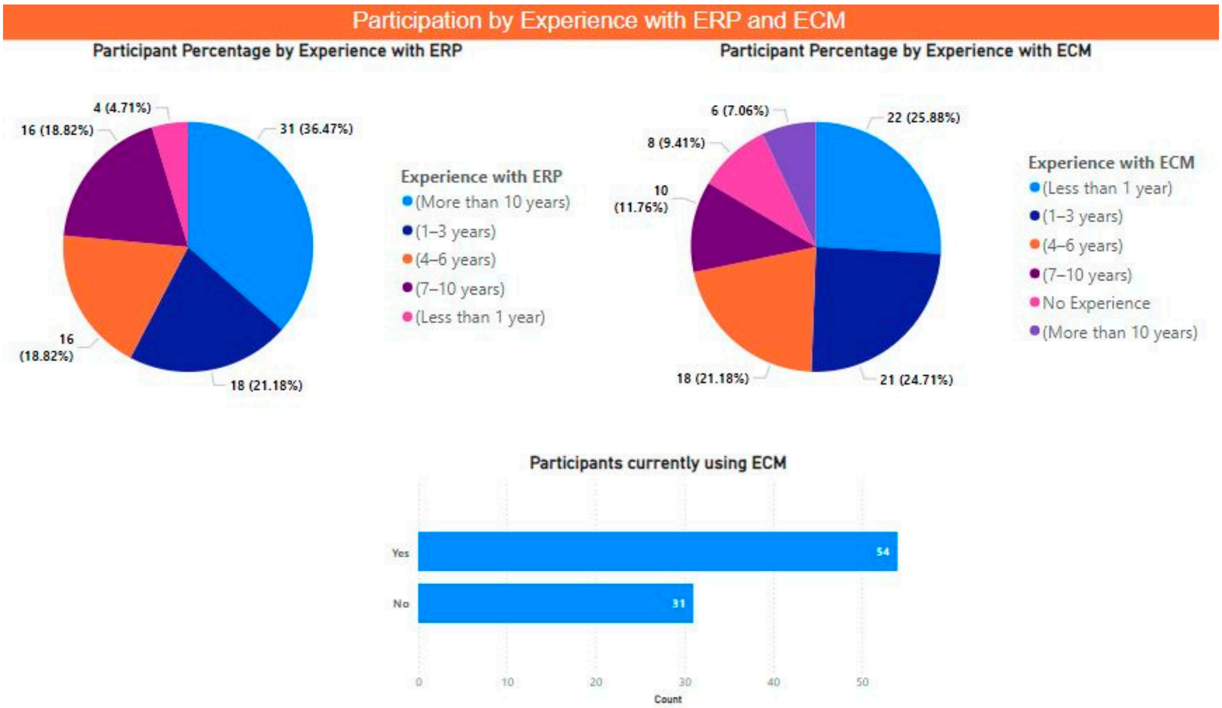


Figure 10. Detailed results of working experience with ERP and ECM.

Finally, acquaintance with BCT was also analysed. In contemporary business and technological platforms, it is one thing to be aware of BCT without any understanding of its workings, and another thing to be reasonably acquainted with the technology. The results revealed that 58.82% of the respondents were somewhat, moderately, or well acquainted with BCT, which is remarkable, since BCT is in its infancy in terms of industry-wide adoption. Figure 11 shows a distribution of BCT acquaintance as well as a breakdown by industry and department.

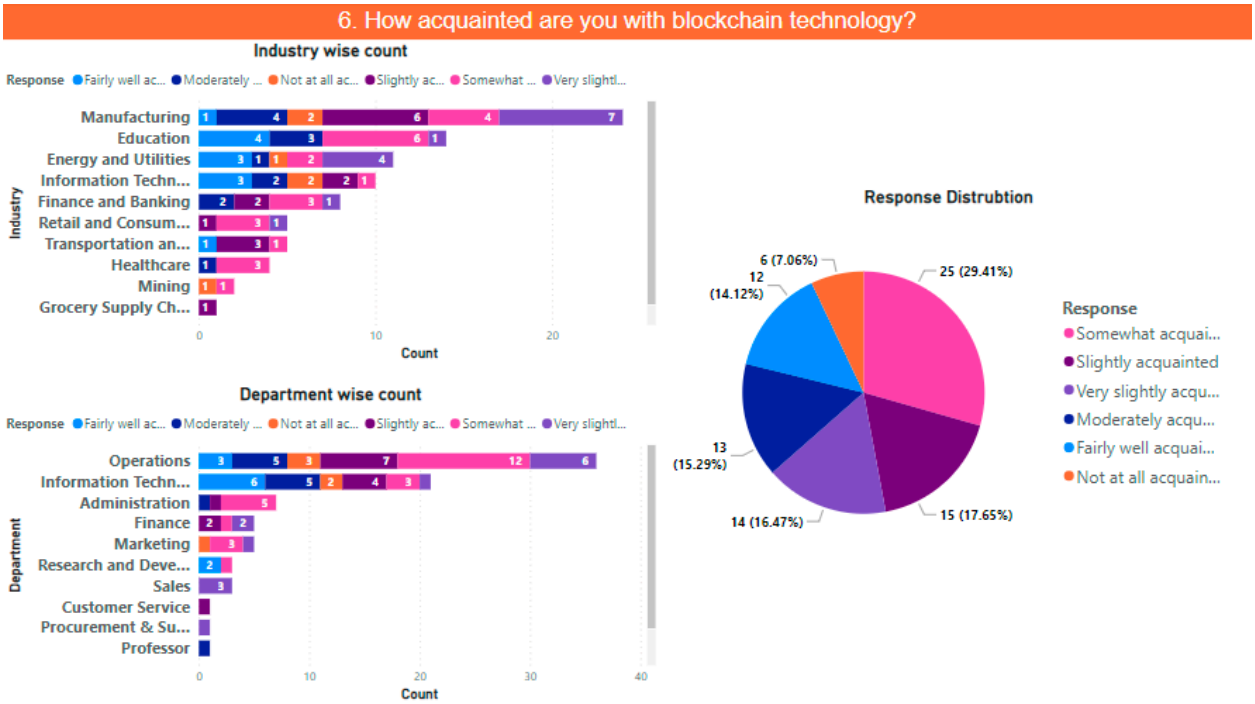


Figure 11. Detailed results of BCT acquaintance.

A descriptive evaluation of the survey item responses was carried out for both the PU and PEU concepts. The responses were analysed using a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). The statistic that represents the value in the centre of the observations typically reveals preliminary insights. Furthermore, the degree to which the observations are dispersed is also important in providing an explicit interpretation. Tables 7 and 8 show the minimum/maximum values and the mean and standard deviation for all survey items, based on associated concept.

Table 7. Summary descriptive evaluation of PU.

Variable	Mean	Standard Dev.	Min	Max
X7.PU.DEPVAR	5.0353	0.9813	3	7
X8.PU.DEPVAR	4.9765	0.9509	3	7
X9.PU	5.1882	0.9939	3	7
X10.PU	5.1294	1.0093	3	7
X11.PU	5.4470	1.2583	3	7
X12.PU	5.4941	1.2112	2	7

Table 8. Summary descriptive evaluation of PEU.

Variable	Mean	Standard Dev.	Min	Max
X13.PEU	4.8117	1.0058	2	7
X14.PEU	4.3529	1.0987	2	7
X15.PEU	4.5411	0.9070	2	7
X16.PEU	4.1647	1.2329	1	7
X17.PEU	4.6706	1.0395	2	7
X18.PEU.DEPVAR	4.6470	1.0657	1	7

According to the results of the above tables, stronger mean values were observed throughout the survey items in relation to the PU concept in comparison to the PEU concept. Survey item 12 revealed the highest mean, 5.49, in Table 7. This outcome corroborates the general opinion about the robust traceability attribute of BCT. Conversely, survey item 16 revealed the smallest mean, 4.16, in Table 8, which suggests a lower perception of the seamlessness of the workflow process.

6.3. Testing of Hypotheses

In accordance with previous analyses that were carried out, the logistic regression model was introduced to test the research hypotheses. Logistic regression is gaining traction in social science research and is rooted in the mathematical concept of natural logarithms [51]. The choice of multinomial logistic regression (MLR) for this study was primarily driven by the nature of the research questions and the type of data collected. MLR is a powerful statistical method suitable for modelling relationships between a categorical dependent variable and one or more independent variables, which may be either categorical or continuous. In this study, the dependent variables are categorical, representing different levels of perceived usefulness (PU) and perceived ease of use (PEU) within a blockchain-enabled engineering change management (ECM) process. Unlike binary logistic regression, which is limited to two outcome categories, MLR is capable of handling dependent variables with more than two categories. This is essential for our analysis, as the dependent variables in this study represent multiple categories of perception, reflecting the nuanced responses captured by the survey instrument.

Preliminary evaluations including the Shapiro–Wilks normality test and a test for multicollinearity were performed to address model assumptions. Results revealed a significant Shapiro–Wilks test value ($p < 0.05$), indicating that the data significantly deviated from a normal distribution. Furthermore, there was no significant indication of multicollinearity, as demonstrated by variance inflation factor (VIF) values ranging from 1 to 10 for the PU concept and 1 to 5 for the PEU concept ($p < 0.05$). Tables 9–11 show the results of these tests.

Table 9. Detailed results of Shapiro–Wilks tests for both PU and PEU concepts.

Variable	W-Value	*p*-Value
X7.PU.DEPVAR	0.89814	0.000005796
X8.PU.DEPVAR	0.86857	0.0000003795
X18.PEU.DEPVAR	0.89877	0.00000617

Table 10. Detailed results of test for multicollinearity for PU concept.

Variable	Estimate	Std. Error	t Value	Pr (>|t|)	Significance	VIF Value
(Intercept)	1.01169	0.38382	2.636	0.0101	*	
X9.PU	0.52413	0.12637	4.148	8.31×10^{-5}	***	3.52896
X10.PU	0.03539	0.10504	0.337	0.7371		2.514247
X11.PU	−0.17456	0.15577	−1.121	0.2658		8.594405
X12.PU	0.36672	0.14425	2.542	0.0129	*	6.828978

The first hypothesis, H1, addressed perceived usefulness in integrating blockchain technology in an ECM-driven ERP landscape. According to the correlation matrix in Table 5, there was a strong relationship between the perceived productivity of a blockchain-enabled ECM process in ERP and all predictor variables within the PU concept. This is demonstrated by an r > 0.5 for all tested relationships ($p < 0.05$ & $p < 0.01$). The symbols (*, **, ***) indicate levels of statistical significance: * for 5% ($p < 0.05$), ** for 1% ($p < 0.01$), and *** for 0.1% ($p < 0.001$). Furthermore, the MLR analysis yielded an impressive accuracy of 84.70%, indicating a robust relationship between the respondents' perception of blockchain-enabled ECM processes within ERP systems and their perceived productivity at work. Table 12 shows the results of the MLR analysis for the PU concept in R statistical software. It strongly supports H1, which posits that the integration of blockchain technology in ERP positively influences the engineering change management process. An accuracy of 84.70% suggests that the model performed well in predicting respondents' perceptions of blockchain-enabled ECM processes in ERP systems. This means that the variables included in our regression model likely captured meaningful relationships between the predictor and response variables, hence indicating a statistically significant relationship between the predictor variables (perceptions of blockchain-enabled ECM processes) and the response variable (perceived productivity at work).

Table 11. Detailed results of test for multicollinearity for PEU concept.

Variable	Estimate	Std. Error	t Value	Pr (>|t|)	Significance	VIF Value
(Intercept)	1.54372	0.53363	2.893	0.004931	**	
X13.PU	−0.09876	0.11156	−0.885	0.378711		1.678068
X14.PU	−0.14907	0.09699	−1.537	0.128314		1.513471
X15.PU	0.09444	0.1473	0.641	0.523296		2.378708
X16.PU	0.3017	0.08134	3.709	0.000385	***	1.340275
X17.PU	0.54428	0.13621	3.996	0.000144	***	2.67174

Table 12. Detailed results of MLR for PU concept.

	3	**4**	**5**	**6**	**7**
3	1	0	1	0	0
4	0	23	5	2	0
5	0	0	21	3	0
6	0	0	0	24	2
7	0	0	0	0	3

The second hypothesis, H2, addressed perceived ease of use in a blockchain-enabled ECM environment. According to the correlation matrix in Table 6, there was a moderate relationship between perceived adequate overall user experience in a blockchain-enabled ECM environment and all predictor variables within the PEU concept. However, the MLR analysis yielded an accuracy of 84.70%, indicating a robust relationship between the respondents' perception of ease of use in a blockchain-enabled ECM environment and their overall ease of use at work. Table 13 below shows the results of the MLR analysis for the PEU concept in R statistical software. It strongly supports H2, which posits that a BCT-driven ERP system will ease usability in the engineering change management process. An accuracy of 84.70% suggests that our model performed well in predicting respondents' perceptions of ease of use in a blockchain-enabled ECM environment, hence indicating a statistically significant relationship between the predictor variables (perceptions of ease of use in a blockchain-enabled ECM environment) and the response variable (overall ease of use at work).

Table 13. Detailed results of MLR for PEU concept.

	1	**2**	**3**	**4**	**5**	**6**	**7**
1	1	0	0	0	0	0	0
2	0	2	0	0	0	0	0
3	0	0	4	0	0	0	0
4	0	0	0	29	3	0	0
5	0	0	0	7	21	0	0
6	0	0	0	0	1	14	1
7	0	0	0	0	0	1	1

6.4. Model Limitations

While logistic regression provides insights into the relationship between variables, it may not capture the full complexity of factors influencing perceptions or outcomes. Alternative modelling techniques could provide a more comprehensive understanding of the phenomena under study. Furthermore, the study's cross-sectional design captures data at a single point in time, which may not account for changes in perceptions or familiarity levels over time. Longitudinal studies could provide more insights into how attitudes towards blockchain-enabled ECM processes evolve over time.

The number of variables explored could be expanded. Including fewer independent variables restricts the depth of analysis, potentially overlooking other influential factors. Including more questions could provide a broader understanding of respondents' attitudes and increase the model accuracy.

The novelty of the topic and scarcity of potential respondents imposes a recruitment challenge. The relatively small effective sample size of 85 responses limits the statistical power of the analysis, where significant relationships or effects are not detected due to insufficient sample representation. A larger sample size would provide more robust statistical estimates and enhance the generalizability of the findings to the broader population.

Finally, survey responses are subject to self-report bias, where participants may provide socially desirable answers or inaccurately report their familiarity with blockchain-enabled ECM processes or their perception of overall user experience. These biases could impact the reliability of the results.

7. Discussion

This section connects the research findings to the existing literature and the research questions that were earlier presented. It also attempts to juxtapose the research findings with those of previous research on the subject. Based on the tenets of TAM, there is clear evidence of "perceived usefulness" and "perceived ease of use" in integrating enterprise systems with BCT to streamline engineering changes. Despite suggestions of a perceived usefulness and perceived ease of use from the descriptive analyses, the results also highlight the need for attention to the aspect of usability. To corroborate this finding, Ref. [52], an exploratory study about the usability of blockchain-based applications, provided empirical evidence that shows how the interactions, metaphors, technical terms, and concepts introduced by BCT impose heavy workloads that are hard to overcome, including for users proficient in ICT. Nevertheless, the study proposed interventions such as a paradigm shift in appreciating new dynamics in web applications by users and improving learnability through the simplification of inherent technical aspects. Questionnaire item 16, pertaining to the seamlessness of the workflow process in a blockchain-enabled ECM environment, was rated the least favourable, as indicated in Table 8's descriptive summary. This may be attributed to a lack of in-depth knowledge as to how the implementation of BCT will impact the workflow management system, judging by a significant number of the survey responses. Conversely, Ref. [53] concluded that blockchain has the potential to serve as an infrastructure for cross-organizational workflow management. Proper workflow management is required and can potentially impact the overall ease of use of technology, especially when users must deal with complex chains of approval within business processes. There are practical implications of not having a robust workflow management system in the operationalization of an enterprise; therefore, it is an important factor to consider when making decisions about adopting a blockchain-driven ECM process. Ref. [54] contended that integrating blockchain infrastructure into workflow management systems and ensuring correctness and security of the workflow execution are important challenges. Nonetheless, there has been a resounding agreement on the perceived usefulness of blockchain integration with parallel technologies and systems in recent research. Ref. [55] involved a pilot study aimed at integrating an academic management system with blockchain for fast and reliable verification of diplomas. The study interrogated users' perceptions of diploma control, veracity, and credibility, and a perception increase across all three categories was found. Ref. [26] provided a practical exploration of how blockchain technology can be integrated with ERP and accounting information systems (AIS) to enhance business processes. It offered a case study focused on e-procurement systems, demonstrating the practical benefits of blockchain integration, such as improved efficiency, security, and data integrity. Ref. [56] presented a detailed case study of Amazon's implementation of Oracle cloud-based ERP, highlighting how blockchain, along with other advanced technologies like AI and IOT, was integrated to enhance operational efficiency. It provided practical insights into the challenges and benefits of such an integration, focusing on how blockchain contributes to secure, real-time data processing and decision making. Ref. [57] investigated the integration of the internet of things (IOT) with BCT to improve employee performance management systems. According to the study, the inherent features of blockchain bolster performance management by inducing transparency and trust in the entire human capital management (HCM) process. In a recent holistic quantitative and qualitative literature study conducted on the integration of artificial intelligence (AI) and BCT with smart agriculture [58], it was posited that the combination of these technologies and concepts have the potential to profoundly impact food cultivation, transportation, and consumption. The persistent interest in research around blockchain integration complements the findings of this research. As evidenced in Ref. [59], the estimated data showed a swift increase of 188% in expenditures on BCT implementation from 2021 through 2024. This increase in spending shows the rapid adoption of blockchain technology, implying its perceived usefulness and perceived ease of use [59].

8. Conclusions and Recommendations

It is imperative to apply a holistic approach in investigating the impact of integrating novel technologies into an existing enterprise landscape. The prevailing research interest in blockchain adoption has heightened the curiosity to explore existing gaps in blockchain applications within business systems and processes. The primary objective of this research was to explore the possibility of complementing enterprise systems with BCT to streamline the management of engineering changes. Poor engineering change management frameworks present several vulnerabilities, especially in manufacturing and e-commerce. E-commerce platforms that rely on product configuration are highly susceptible. This study employed a TAM framework to interrogate users' perceptions. Two concepts were examined: perceived usefulness (PU) and perceived ease of use (PEU). The research found statistically significant relationships between the perceived productivity of blockchain-enabled ECM processes in

ERP and all predictor variables within the PU concept. This result validated utility, and therefore, implied perceived usefulness. The research also found statistically significant relationships between perceived adequate overall user experience in a blockchain-enabled ECM environment and all predictor variables within the PEU concept. The relationship, even though moderate, validated usability and, therefore, implied perceived ease of use. These findings provide valuable insights to both academic researchers and the practice community by filling a gap in the literature with regards to the integration of blockchain into the enterprise landscape to resolve issues of transparency and security. While previous studies have covered the integration of blockchain with artificial intelligence, performance management systems, and diverse web applications, work on integrating it with change management process is sparse. A few studies, including [60], have conducted literature reviews about managing change with blockchain in accountancy and auditing organizations, as well as other areas of application. However, the general literature lags regarding perceptions of BCT adoption. The empirical findings of this study will help practitioners to understand key areas to focus on when planning future technology adoption. The research identified workflow management as an important area that may impact perceived ease of use. Future research requires more technical and robust investigations, especially around the intricacies of workflow management in a blockchain-enabled platform. As previously mentioned in the model limitations sub-section, the sample size is important with regards to the statistical power and the generalizability of the findings. The novelty of BCT contributed to the small sample size achieved in this research. Hence, incorporating a qualitative data collection component in future research could confirm or contrast with the current findings.

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