Addressing Engineering Change Management in Industry 4.0 using Blockchain Technology

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Abstract

Engineering Change Management (ECM) is critical for ensuring that frequent product and process modifications in modern supply chains do not erode cost, quality, and delivery performance. However, ECM in practice is often hampered by fragmented information flows, limited transparency between stakeholders, and weak traceability of decisions and product states, especially in globally distributed Industry 4.0 environments. This research investigates how blockchain technology can support ECM by enabling secure, transparent, and timely exchange of engineering and logistical information. First, an extensive literature review is conducted to synthesise ECM challenges and relevant Industry 4.0 and blockchain capabilities. Building on this, a comparison framework is developed that models information flows in a typical supply chain with and without blockchain support, using a cloud-based distributed ledger as the core enabler. The framework is complemented with multiple industrial case studies (BMW, KUKA, RHI Magnesita–Gerdau, Samsung) to illustrate concrete design patterns for blockchain-enabled traceability, asset tracking, and data protection. Finally, an online survey of industrial practitioners is carried out to assess current familiarity with blockchain, frequency of ECM, typical communication failures, and existing response strategies. The combined findings indicate that while practical adoption of blockchain in ECM is still limited, its properties of immutability, shared visibility, and secure access control can alleviate key ECM pain points related to communication delays, error propagation, and late detection of complexity. At the same time, technical and organisational barriers such as scalability, energy consumption, and lack of expertise constrain current deployment. Overall, the study positions blockchain not as a universal solution but a targeted enabler. The paper concludes with implications for researchers and practitioners and outlines a roadmap for future empirical studies on blockchain-enabled ECM in Industry 4.0 supply chains.

Keywords: Engineering Change Management; Blockchain Technology; Industry 4.0; Supply Chain Management; Information Flow; Traceability; Digital Transformation.

1 Introduction

The industries that work on complicated commodities have evolved dramatically in the last two decades[1]. More personalized products are being requested in the market, resulting in organizations having to cope with several variations in the same category[2]. As a result, Concurrent Engineering approaches and methods were developed to improve collaborative work procedures[3]. Engineering Change management (ECM) is a crucial logistical function that is used to change numerous and diverse qualities of basic production data[4]. Engineering change management is very essential and when it is done well, it can provide a great opportunity to improve development efficiency. If done incorrectly it can lead to higher costs and a lot of errors in the project[5].

ECM can control, automate, and synthesize all the requests, assessments and plans made to a system when changing the products or process qualities. In addition, it plays a crucial role of ensuring that the product or process information is correct as well as monitoring and supervising the product's development[6,7]. An ideal Engineering Change Management would contain a full description, analysis, and effect of a change. This method is important as it achieves improvements in quality, waste reduction, ensures lower product disruption and is a very cost-effective implementation[8]. However, minor problems when implementing this strategy can have major and drastic effects, such as manufacturing process disruptions, receiving the wrong materials from suppliers, warranty claims on malfunction products, and delivery problems, as in delivering the incorrect products or late deliveries which can cause penalties[8].

To implement this function, it is important to first understand the problem and see what should be changed. After that an Engineering change request (ECR) must be created, an ECRis a proposal that can be submitted to management to help find the solutions to complicated issues or modify and enhance products[9]. A good description of the following details which are the expected outcomes from change, the reason for change, expected costs and obstacles, and of course, any valuable information that can be useful when creating a request, these details can improve your chances when presenting an ECR case. In addition, it can always be helpful when discussing the case and seeking feedback. Once an ECR is approved it is change to an Engineering change order (ECO). An ECO is an approved document from the authorities, that explains and grants permission for an

engineering change to be made to the products. Once the ECO is granted, preparations and implementations to changes can begin, in parallel to this, it is vital to keep documentation and communication updates throughout every stage in the engineering change. Once, completed the ECO status can be closed and of course the result should be documented andcommunicated to relevant parties[10].

Figure 1: ECR Workflow

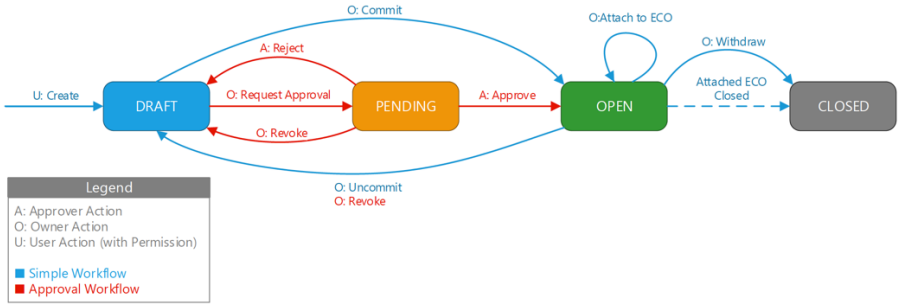

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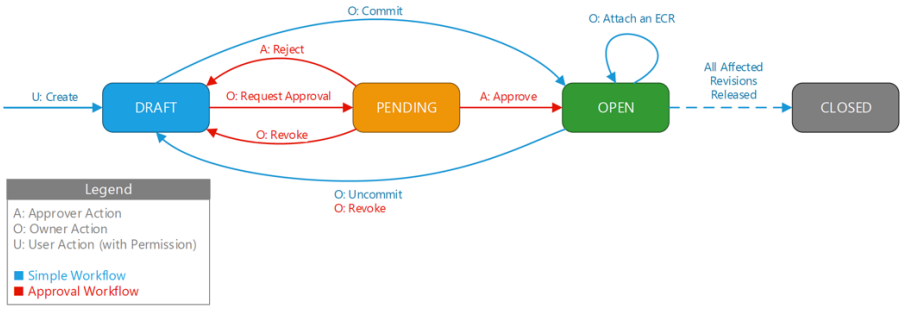
Figure 2: ECO Workflow



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1.2 Problem

For Engineering change management to do well it must rely on three pillars, which are the people, processes, and technology. The project will not work if the people involved are not fully engaged and occupied with their part in the project, in addition to that the project will also not work if the processes are not reliable nor well established. Technology should be able to back strong governance, as it is important for it to be included in organizational processes. If these pillars are not supported well then engineering change management will be complex and tough. The following scenarios will make executing engineering change management more difficult: ECM should be approached as a cultural and overall

business change and not an IT project, as it must be acquired by the entire organization. People may not fully understand the complex effects ECM can have despite understand the mechanical process. In addition to that, people are not fully involved because of they were very invested in the old methods and do not understand new processes. Another point would be lack of strong leadership support, the people at the top must be engaged and have a well understanding of the process. Also, system and processed usually cause delays, so a loss of control can cause people to worry, this may cause them to work inefficiently[12].

A challenge within the ECM is controlling the change propagation. Engineering Change management usually encourages a sequence of down-stream changes beyond the company, consequently, various functions must adapt to deal with engineering changes and their effects throughout the entire manufacturing company[13,14]. These changes are usually triggered from: Suppliers, such as changing to a new supplier, in addition to that, important supplier usually struggle to meet deadlines which can result shortages. As well as customers that have late inputs, tests that are unpredictable and results from validation that cause design changes that delays the processes[15]. A third trigger from the internal department, for reasons such as reducing costs, upgrading quality and reliability, etc. Four major factors that can further lead to propagation changes are, forgetfulness and oversight, lack of expertise and system knowledge, communication failure, and complex system for emergent properties[16].

Another challenge that ECM faces is the distribution of it in collaborative engineering, which basically means that during a product's development lifecycle it goes through many stages between participants with different disciplines and functions, most work in teams and are distributed across different sites, this is a complex challenge due to the fact that in today's engineering activities, the production of a products has to go through a global environment, with different manufacturers, suppliers, providers, etc.[16]. This results in a longer decision making, as to when more people in different sectors must meet and consult between one another, the lead time will increase the project lead time. Another effect it may have is that it cause tension and conflicts in the project, especially when team members are struggling to agree on certain key points about the strategy and implementation[17].

A third challenge would be the management of late changes. During a product lifecycle, many major factors can cause changes to the phase they take place in. Usually, during the manufacturing or build and test phases, major changes happen to them, and they are the most dominant phase that requires change. Normally, the later the changes are carried out, the higher are the costs, compared to the early changes. Early changes are usually more flexible and not very costly when creating a process or product[16].

Finally, a fourth challenge engineering change management faces is the constant complexity growth of products. Complexity has two types it can either be “product-related complexity” or “structure-related complexity.” The number of products or components they are made up of or the type of raw materials that are used are product-related complexity. The number of factories, markets, warehouses, or suppliers are the structure-related complexity. A lot of small decisions along the way can add up and increase complexity. Being able to manage the products/processes complexity can lead create value and reduce costs[18]. This can be evaluated from the constructional point of view, technological point of view, and the number of variants and parts. Generally, the more complex the product is, that harder of a task it is to maintain the complete concept for the system. In addition to that, the higher complexity in the product, means that production processes must be carefully planned, communication channels must be better and more secure, and the higher the association between different departments in the manufacturing company[16].

1.3 Research Aims

The main objective and aim of this research is to find and choose challenges and obstacles that Engineering change Management faces, and to look for a solution using blockchains inindustry 4.0.

The first sub-objective in this research is to find blockchain technology that can solve the problem of changes in the product life in engineering change management.

The second sub-objective will be looking at how blockchain technology can connect all time conflicts.

The third sub-objective would be using the blockchain technology to focus and improve the quality of processes/products rather than the quantity of system.

1.4 Course of Research

First, it will start with a detailed literature research review to pick out a big and crucial obstacle that the industry faces and how it affects the production and procurement in the supply chain of engineering change management. Second, the analytical course of this will be holding and conducting a study to detect how components of industry 4.0 can help in solving the problems found in engineering change management. The data will be gathered then analysed and compared, once finding the best solution, it will be used and conducted in an experiment, and noticing how it behaves in the industry. Then, a questionnaire will be created and a discussion on the following topic will be made. After that the limitations of the research will be talked about and how they can possibly affect the findings. Finally, a summary of the analytical course will be shown and help to help point outall the key findings and the behaviours.

2 Literature Review

2.1 Industry 4.0

The transition from an agricultural and handcrafted economy to a new economy driven by industry and machine production is known as the Industrial Revolution[19]. The Industrial Revolution originated during the 18th century in Britain, but it quickly expanded across the rest of the world[20]. This historical shift is accountable for population growth, improved living standards, and the capitalist economy's creation[21]. In today's modern world, we are entering the fourth industrial revolution, industry 4.0, there has been huge progress since the first industrial revolution[22].

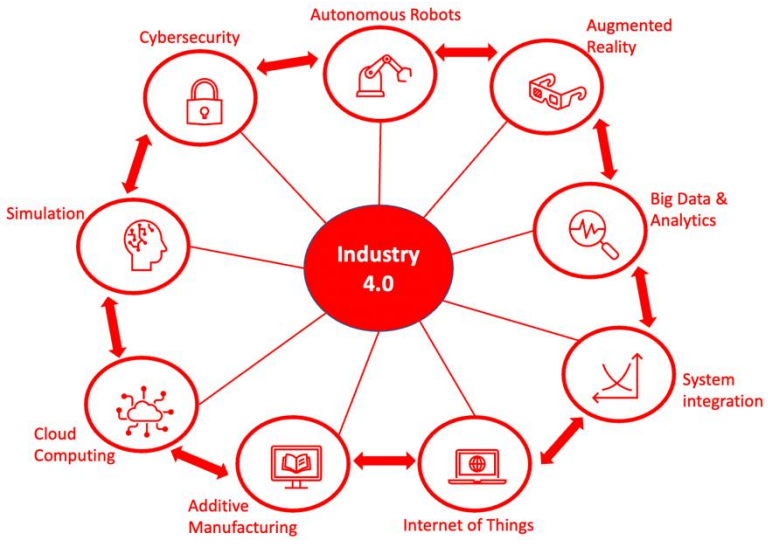
Machines performed the very first mass manufacturing in the industry 1.0 period. Water and steam were used to generate them, this new type of drive greatly enhanced production[23]. Advanced technological system were established in industry 2.0, especially electrical technology, which enabled far better manufacturing processes and advancements in machinery[24]. Industry 3.0 originated from the utilization of advanced electronics, telecommunications, and computers to partially automate processes. Currently we are able to completely automate production processes without the need of human interventions, thanks to the development of these technologies[25]. Finally, Industry 4.0 is the combination of clever and creative information with new communication

technologies into the value chain by joining and computerizing traditional operations. It is changing the way businesses produce, develop, and distribute their goods[26].

The Fourth Industrial Revolution signifies a significant shift in how we live, work, and interact. It's the beginning of an era in human growth, made possible by incredible technological advancements[27]. This revolutionary prototype targets promoting intelligent networking of products and processescausing a decrease in complex operations, at the same time an increase in efficiency and effectiveness with the long-term cost reduction and processes improvement[28]. The creation of smart cities which decrease the levels of poverty and raise living standards, using energy sources which are, protect the environment, improve participatory government processes, social cohesion and communication, and better health will all be part of Industry 4.0[29]. This digital world will ensure that far more components of a manufacturing line, both within and without the facility walls, are connected instantaneously[30].

Industry 4.0 is created from 9 technological applications which include: (1) Big data & Analytics, (2) Cybersecurity, (3) Industrial Internet of Things (iIoT), (4) Simulation, (5) Augmented Reality (AR), (6) Autonomous Robots, (7) System Integration, (8) Additive Manufacturing, (9) Cloud Computing[31]. These advancements connect both the real world and the virtual world together, enabling intelligent and autonomous system[32].

Figure 3: Applications in Industry 4.0



Big data analytics is the use of modern computer tools to large data sets in order to uncover useful connections, algorithms, trends, and preferences that may help businesses make smarter decisions[33]. The cyber security principles are intended to give clear plans on how to safeguard a company's system and data against cyber-attacks. These four main actions are: defining and monitoring security risks, establishing security measures to decrease security risks, then detecting and analyzing cyber security occurrences to uncover security breaches, and reacting and recovering from cyber security attacks[34]. Being implemented to the manufacturing business, the iIoT is a notion of merging intelligent manufacturing equipment, AI-powered automation, and sophisticated analytics to assist in making everything more efficient. iIoT will transform manufacturing by allowing significantly bigger volumes of data to be acquired and accessed quicker and more effectively than there has ever been[35].

To make better decisions, simulation is an important tool as it creates planning and research models, in addition to designing and operating complicated and intelligent manufacturing system[36]. AR is a key component of this industry's principles because it allows users to access digital data and display it on the real world[37]. Autonomous robots have become increasingly self-sufficient and collaborative. Robotic system can communicate with each other to increase production and quality of their products. These robots could handle more difficult jobs and unanticipated challenges[38].

Within the domains of engineering and information technology, system integration is a widespread practice. It entails the integration of several computer system and software programs to form a bigger network, and that's what propels Industry 4.0 forward[39]. Additive manufacturing is a collection of production technologies that enables the creation and further layering material to create a finished product. Benefits can include: Lower waste production, prototyping times and expenses are reduced, encouragement of businesses to go digital, and it reduces the assembling procedure to a single component[40]. Cloud computing refers to the process of data storage and acquiring applications through the Internet rather than a computer’s hard disk[41]. It can allow organizations to have access to the most up-to-date information, operations, and programs because of the new digital revolution without the need to invest much in a complicated physical infrastructure. As corporate demands and technological choices change, cloud-based solutions can simply adapt and adjust[42].

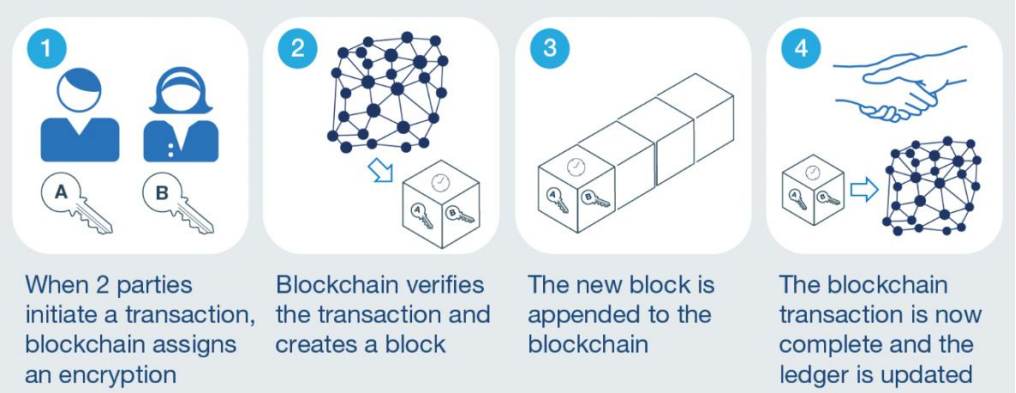
2.1.2 Blockchain Technology

Industry 4.0 includes advancements in emerging digital technology, including blockchain[43]. Within the next decade, blockchain technology will evolve in a variety of ways. Digitalization is a critical aspect of Industry 4.0. It enables businesses to increase productivity across the board, from supply chain strategy and blockchain solutions to management and technology consultancy to supply chain solutions. Many sectors might benefit from this blockchain technology[44].

The blockchain may be defined as a technology that enables a collection of linked computers to keep a singular, up-to-date, and secure ledger[45,46]. A blockchain organizes data into sections called blocks, each of which contains a collection of data. Blocks have specific storage capacities, and when they are full, they're closed and connected to the preceding block, producing a data chain known as the blockchain[47]. Every operation is separately validated, time-stamped, and joined to a growing chain of information using peer-to-peer networks. Information cannot be changed after it has been recorded[48].

Industry 4.0 needs the complete connection of several system and technologies throughout all sectors. When developing smart factories applications, this poses several issues, like security, trust, traceability, reliability, and agreement automation across the entire value chain. Most of those issues can be solved with blockchain technology[49]. They have the potential to make processes more organized and efficient, as well as increase clarity and are extraordinary when it comes to asset tracking. Possibly they can reform the manufacturer’s design, engineering and how they make and scale their products[50,51]. A few obstacles day-to-day engineers face can be solved using blockchains such as: Assuring quality, tracking their assets, Transparent supply-chain surveillance, detection of counterfeit materials, Engineering complex products and processes. It can tackle all these problems and more, as well as provide crucial values to industrial companies[52].

Figure 4: How to create a blockchain transaction



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Blockchains are tamper-proof distributed information frameworks for which records are kept in chronologically and charted in a comprehensible and unalterable format without relying on centralized control. Since it operates on the premise of continuous and unalterable data recording, blockchain technology allows users to store and maintain possession more quickly and reliably than ever before[54]. Additionally, each block in the blockchain is encrypted and distributed to every member, who have their own copies of the blockchain. The blockchain can provide a full, trustworthy, and tamperproof audit trail of activities in the supply chain. A shared blockchain can be able to accompany logistical data, track the shipments, and make payments automated without needing big changes to the firms' internal processes or to their information technology system[55,56].

2.2 Blockchain Technology in Supply Chain

A supply chain is a system that connects a firm with its suppliers to manufacture and deliver certain goods to the end consumers. Various tasks, individuals, organizations, information, and resources are all part of this system. The supply chain also depicts the stages involved in getting a product or service from its initial condition to its final destination[57]. The goal is to enable a small group of trusted entities to communicate directly with each other while enhancing security, assuring contract compliance, and lowering expenses[58]. Technological advances are giving exciting potential for economic growth. The use of blockchain in the supply chain has the ability to increase the level of transparency while also lowering administrative expenses[59]. Today, supply chains around the world are all in desperate need of a systematic strategy to organizing information in a secure manner, which can aid in the development of a methods for evaluating risk and

preventing disturbances. Blockchain Technology may be used to create such a risk-based structure[60]

Natural disasters, accidents, and purposeful disturbances are all risks to a supply chain, and their probability and repercussions are increased by complex, supply chains with everlasting product lifecycles, and dynamic and uncertain marketplaces[61]. The supply chain's ability to resist and quickly recover from any disruption it may face is defined as a resilient supply chain. A supply chain that is genuinely resilient has to be able to foresee and detect disturbances, and in many circumstances, completely prevent them[62]. If one part of the entire supply chain is being exposed to any disruption, then it is at risk and the entire supply chain will be negatively affected and could cause it to break down[63,64]. The blockchain is a peer-to-peer system of data technology that utilizes distributed ledgers to retain information of digital asset exchanges which are not controlled by third parties like as banks or governments. Resulting in a reduction of risks associated with intermediary involvement, such as cyberattacks, endangered privacy, political uncertainty, expensive compliance with federal norms and regulations, financial institution instability, and contractual conflicts[65].

Recently businesses have had high pressure to show better responsibility environmentally and socially by their stakeholders such as consumer, workers, shareholders, and governments[7]. This is now occurring in a period in which organization's case for long-term sustainable activities is becoming increasingly compelling. Supply chains seem to be a target to many firms because they consume a huge number of resources and revenue and are usually a risk to the environment. As a result, supply chain sustainability has become a top business priority. Companies have begun to track the social and environmental effect of their products and services over their entire life cycle[66]. A sustainable supply chain is one in which social and ecologically responsible operations are completely integrated into an effective and profitable structure[67]. Environmentally sustainable supply chain management and procedures may help businesses in not just reducing their overall carbon footprint, but also improve the end-to-end processes to save money and increase profits[68]. Blockchain Technology assists businesses and governments in acting more sustainably by shutting down unlawful and immoral behaviours. The technology provides unrivalled transparency, which can assist eliminate environmental violations[69].

Smart contracts and blockchain technology might bring different benefits in terms of implementing business intelligence. First and foremost, it can help with inventory tracking precision. Furthermore, blockchain applications in supply chain management improve the transparency about rights of consumer products from raw material to the final of point consumption. Most importantly, the applications of this technology in supply chain promote the advantages such as improved goods, program, and service licensing[70]. These applications create trust between different stakeholders and improve relationships between organizations, as every member of the supply chain can store their own records and trust the data. In addition, it creates transparency which tracks and records all the product's data in its life cycle from start to end, including data that isn't recorded in a traditional supply chain. This allows better understanding of the supply chain and quicker resolutions to disputes. Finally, it increases the efficiency by being able to notice disruptions as they occur, which gives more time to be able to recover from the disturbance, as well as being able to see its tracking history, requires less time wasted on trying to know where it went wrong[71,72].

2.3 Case Studies

2.3.1 BMW Group

Blockchain technology is expanding and is being implemented further in this world, a good example would its use in the automotive industry. In April 2020, the BMW group, one of the leading organizations in the automotive industry, have announced that they have begun using blockchain technologies to be able to track the international supply of their spare parts. The BMW group have called this function, the "Partchain." The automotive industry is a very complicated system it requires many factors at different delivery stages, and they usually go through a lot of changes[73]. Andreas Wendt, a member of the Board of management in BMW, has said "*Partchain enables tamper-proof and consistently verifiable collection and transaction of data in our supply chain.*" This means that the Partchain function is mainly used in tracking the components from the very origin of the raw materials until the end without any risk of manipulation[74]. This would give the organization a clearer perspective on the supply chain to make auditing easier. To do this, Partchain will be using cloud technologies in addition to other blockchain solutions[75].

BMW's supply chain is vast, with significant and, above all, complicated international implications. Until now, every one of the stakeholders in this ever-changing network had a tendency of handling information by themselves[76]. The organizations' IT system were not really capable of interacting with eachother regularly. Providing openness required a significant amount of human effort on the part of the BMW Group's buying specialists and suppliers[77].

Using functions similar to BMW's Partchain function can allow organizations to utilize them when applying engineering change management. It can solve a few challenges that are commonly faced in that area such as the challenge in the distribution of collaborative engineering. In my opinion, utilizing the Partchain function can help be decrease the project's lead time, by decisions to be made faster since they have clearer information about the component from the very beginning to the very end. I also believe another challenge that the Partchain can solve in engineering change management would be the management of late changes problem, because it is capable of tracking the component from the very start to the very end, this can create a solution for the late changes, by noticing early errors.

2.3.2 KUKA

Another famous organization that is pioneering in the industry 4.0 is the KUKA Group. KUKA is a leading of the open industry 4.0 alliance. The open industry 4.0 alliance is an open ecosystem that is used for the digital changes of the industrial manufacturing plants. This alliance's goal is to be able to master the industry 4.0 and allow businesses to reach new heights, they do this by helping their clients to smoothly adapt to the industrial internet of things[78]. In KUKA's supply chain they focus on using RFIDs and sensors in all their processes, to make the record keeping and tracking of their products easier. This function allows operators to be able to follow and observe the product's timeline and prevent problems before they grow into worse situations[79]. RFID, short for 'Radio Frequency Identification', uses intelligent barcodes to identify items when tracking them. They transmit data automatically from an RFID tag to a reader which then can be transferred to a RFID computer software. An RFID tag is a microchip/antenna that transfer and receive data with either a battery or electromagnetic energy[80].

In KUKA's matrix production, they use AGVs (Automated guided vehicle), they use it to automatically transfer the components which are supplied from the robots. With the RFID

transponders placed on the component's fixture, allows it to detect movements, by reading and writing data when the component leaves or enters the cell. The data it contains the component's weight, time it takes for maintenance and to operate, and as well as the errors that occur. This information is all transferred out to the KUKA Cloud and analyzed. This all allows the operators to have control over the process's data, to develop and improve it, in addition it can be available globally, to give commercial advantages[81].

From my point of view the use of RFIDs can solve many common engineering change management challenges such as the controlling the change propagation. An advantage from it would be its potential to solve the complexity challenge in engineering change management, I believe it can do this by analysing all the component's data in the processes. Being able to do so and spot the component's or processes' complexity errors and Not-OK applications as early as possible can make it easier and faster to tackle the challenges that can be used in a supply chain when undergoing ECM. By making all the information available and stored on a cloud-server that keeps track of what is happening, it will connect all the departments together with the ability to be simply distributed to whoever requires the information in real time, in addition to strengthening the company's security.

2.3.3 RHI Magnesita & Gerdau

RHI Magnesita, an organization leading the market worldwide with innovative technology in refractories and Brazilian organization known as Gerdau in the steel industry, are yet other companies that have jumped on the blockchain bandwagon. They are using a software to improve Gerdau's mill's performance in Minas Gerais state. They called this software: Refrac chain. It is used to take the measurement of performances of the refractory items that RHI Magnesita supply to Gerdau[82]. Gerdau and RHI Magnesita have formed a joint venture to assess performance contracts using blockchain technology. The project will use blockchain to track transactions and data with financial computations. Furthermore, rather to hand, disjointed analysis, performance measuring activities would be performed continuously by a specialized software[83].

All the data that were tracked manually will now be recorded using blockchains in their software. This project between the two organizations will assure better performance of the refractory items that are supplied[84]. Another addition that this project between these two organizations would be increasing transparency between them, which will create trust

and confidence in the operations they perform together and increase their decision making speed[85].

These softwares, such as Refrac chain, can be expanded and used in other projects or operations, and if necessary, it can be included in engineering change management. Using it in engineering change management can be able to speed up processes and counter challenges that it faces such as controlling change propagation and its distribution in collaborative engineering. As it allows transparency between both organizations involved, which gives them confidence to make decisions faster and be able to work together more efficiently. As well in assessing performances, that can be used to detect faults and work on them together with certainty.

2.3.4 Samsung

Samsung is a South Korean electronics manufacturer that is among the world's biggest manufacturers. Samsung manufactures a range of industrial and consumer technologies, such as utilities, digital media products, semiconductors, memory sticks, and system integration. It is now one of the best known technological brands, accounting for almost a quarter of South Korea's export value[86]. Samsung Blockchain stores private keys inside a singular, safe place and uses the secret keys key to encrypt your records. All digital properties are safeguarded and your data are exchanged safely using Private Share[87]. Samsung Blockchain Keystore gives users control over the information by allowing them to keep and maintain secret data analysis tools in a secure environment. The secret key and data held inside the Samsung Blockchain Keystore won't be saved to a Samsung or external cloud, and they are never visible to the Android OS on the gadgets. This enables it to offer unprecedented privacy, safeguarding data against cybersecurity incidents, viruses, and other dangers[88].

In an Engineering change management process, system are more prone to security threats. ECM requires quick and broad transfers of information between different departments, this can result in information leaks and is also makes the information more vulnerable to be misinterpreted which can slow down and maybe in some cases threaten projects to collapse. However, I strongly believe that using tools similar to that of Samsung Blockchain Keystore, can minimize the security threats received from changes, by storing

all the data in a secure and safe place. In addition to that it can help in developing the supply chain by increasing its resilience, by avoiding threats and storing important data.

3 Methodology

3.1 Comparison Framework

In this chapter a comparison framework was created to compare the sequence and flow of information between different departments in an organization in a logistical supply chain. After understanding and evaluating the case studies and understanding the use of blockchain technology and how it interferes in the supply chain. Major findings have been noticed when comparing the processes of information flow.

From the information gained from the literature review, two workflow figures have been created to show the flow of information in the supply chain when going through Engineering Change Management. In which the first figure shows the process without the use of blockchain technologies in its supply chain and the complicated sequence that the information flow must undergo when changes are made to the processes. On the other hand, the second workflow figure created will show the use of a blockchain technology in the supply chain when going through Engineering Change Management, it was noticed that the second workflow figure appears to be much less complicated than the previous model, that does not use blockchain technology. The blockchain technology chosen to be illustrated in the second figure was the development of the cloud server.

3.2 Information flow without Blockchain technology

In reference to Figure 5, it can be shown how the transfer of information is being passed along the supply chain when there is an engineering change management application. First it can start with the customers who place their order and may sometimes change preferences and request changes to be added to their product. The information from the customers will be given to the sales departments, however information flow both ways, as the sales department will have to decide the prices and give feedback and updates regarding their product's status and the processes that involve that product. The sales department would then have to communicate between themselves for different requests.

The sales departments would then have to spread that information to the workshops, to give them new information regarding the customers' requests for the creation the product as well as constantly updating them for any new changes the consumer might

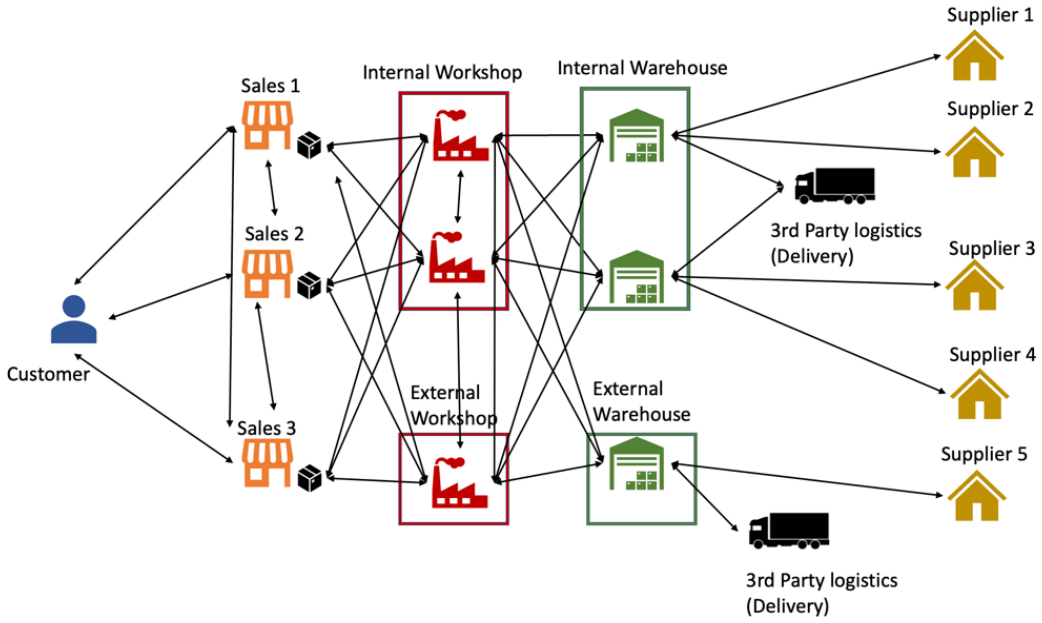
have requested. In addition to that the workshops will constantly have to be updating the sales on the status of the products, the inefficiencies, the delays, and any sort of challenge they may face in during their operations, so that the sales departments can keep the customers up to date. Some workshops can be found internally and for some other cases, when certain organizations do not have the abilities for certain product developments, they may have external workshops. To understand and recognize the processes, all the workshops must communicate and transfer necessary information between one another often, at the same time make sure that all internal information stays internal and does not get mixed up with outer sources, furthermore they would also need to be as transparent as possible to build trust between one another. To request the necessary raw material the internal and external workshops would also need to communicate to the warehouses as to know which raw materials are needed for the creation of the customer's requested product. What's more is that certain supply chains may also not have enough storage and space in their warehouse and could also require some external warehouses to store additional raw materials. So, as previously mentioned constant external and internal communication becomes more prone to be mixed up and security can be threatened. Especially if the organization has a weak security system.

The warehouse will also be giving necessary information such as disturbances in its supply chain and inefficiencies of certain materials that were needed to fulfill the customer's request. Other sources of information it can give to the workshops could be the delivery status and the delays that it may face in the delivery and transportation of materials updating the workshops on the delivery status as well as any inefficiencies or disruptions they face. The Warehouses would also need constant communication with 3rd Party logistics, to make sure everything is meeting its deadlines as well as communication to suppliers to order certain raw materials needed in their processes to finalize the creation of the final product. The information will be moved in both ways, one for the request regarding the wants and the other will be replying with updates.

It is also critical that information is passed both ways, such as delays from the other side, missing products, costs, and internal/external information. As it is shown that a lot of information is needed to communicate between the different departments in the organization's supply chain. A lot of information can be lost, misunderstood, delayed, or even leaked, especially when communication with external sources. In an ECM, when the

customers must give constant updates on what changes they would like for the development and creation of their desired final product. Making sure that the product is not too complex when designing it and that everything is timed correctly, without delays in applications will be a hassle, particularly when delays are caused when passing along of information to different departments in the organization's supply chain. Another complication noticed could be if the organization faces internal or external changes in staff, management, capital, location and so on. These changes will cause difficulty in understanding the data when new information is passed, as trying to understand previous changes will be more complex. Finally with the constant flow of information between departments it will be difficult to maintain as it can be easily leaked, especially when the organization has a weak security system in its supply chain.

Figure 5: Information Flow Sequence in a Supply Chain without Blockchain Technology



3.3 Information flow with Blockchain technology

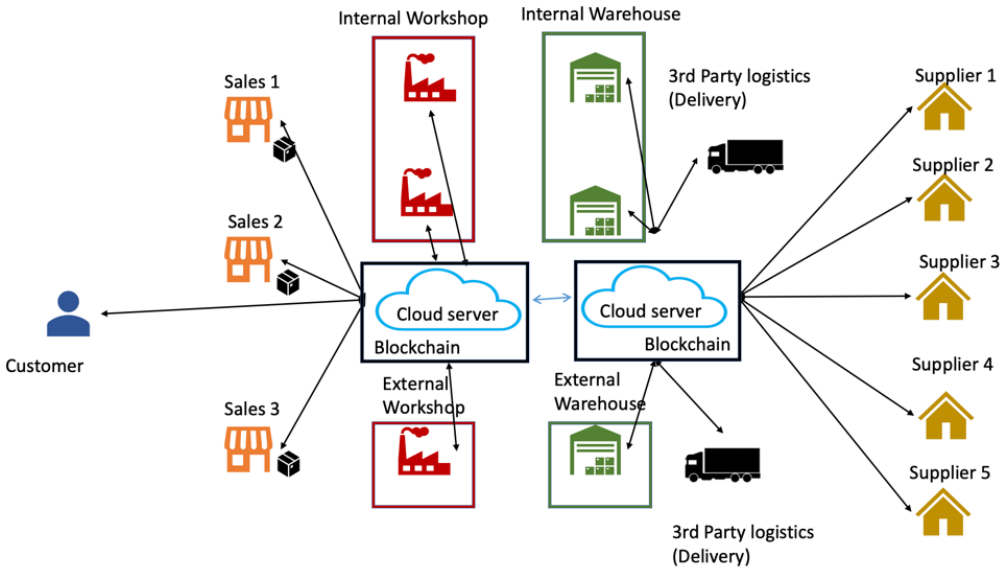
Now when looking at a workflow model that uses a blockchain technology solution in its supply chain, as shown in Figure 6. It can be noticed that all the information between the different departments will all be stored together in a secured block which can give access to whoever may require the new information, in real time. The blockchain technology shown is the cloud server which gives access to whoever may requires it.

For example, when a customer makes an order or decides to update changes to a previous order, it can be shown in the cloud server for whoever may require the information, such as the employees in the workshop, instead of waiting on receiving information, they can be able to deal with changes as soon as possible, as it will be shown in the cloud server in real time. As well as any changes from any stakeholder in ECM can be noticed and dealt with as quick as possible.

In addition to that is that confidential information is hidden from the departments that do not require them. As the cloud server application enables privacy and security between departments, any confidential information will be secured for whoever has access to it. However, it can also offer transparency, as any other regular data can be shared with all those who may require it for their operations, this will result in less time being wasted on company disputes, as the data shown will be transparent and the same for everyone. In addition, as discussed earlier blockchain technologies are known to be very secure and having strong cybersecurity system in their supply chain can minimize the threatened cyberattacks and data leaks in the organization.

Finally, another important feature that blockchain technology applications have is their traceability. All the products created can be tracked from the very beginning as they were a raw material till the very end, being a final product that is sent out and distributed to the customer, so the status of the production operations will always be available on the cloud server and whoever may require this information can be able to gain it. This can allow processes to be much more efficient, and less time will be wasted on information travel when trying to understand where the disruptions have occurred. Additionally, when mistakes are found in the supply chain it gives the stakeholders responsible for them more time to be able to quickly recover from them and bring the supply chain processes back on track. Lastly, when tracing the product, as it goes through its production operations, blockchain technology can also notice when the complexity of the processes and product in the supply chain is increasing and can give real time update on that challenge, instead of detecting the high complexity in the later stages in the supply chain.

Figure 6: Information Flow Sequence in a Supply Chain with Blockchain Technology



4 Methodology

The objective of this research is to be able to get an insight and understand how organizations deal with engineering change management in their supply chain, as well as the challenges and complications they face in the process. In addition to the use of blockchain technology in their process and what role it influences if used when developing the processes, the organizations go through and solving the challenges. Thus, organizations from different industries will be analysed and reviewed to see their techniques and methods once going through changes in their product developments.

4.1 Research design

An online survey, which is one of most popular data-collection methods was used, it is a series of questions distributed to a selected group and the participants answer through the Internet[89]. In the online survey, a series of questions were formulated with the information gained form the literature review. The survey was shared online, and it selected targets that have experience in working in today's real-world market. The questions were used mainly to ask the participants about their understanding and knowledge of blockchain technology applications as well as gaining further insights and

understands of what the respondents may face when undergoing engineering change management, in their organization's supply chain in today's market (Appendix 1).

Different types of questions were put together in this research, first off were the Likert scale questions. The Likert scale can give a measurement scale on the respondents' agreements, perceptions, ability and quantity on various statements[90]. The questions asked in this model was first to understand and measure how familiar the respondents are with blockchain technology applications. Additionally, the Likert scale was also used to measure how often do certain organizations go through ECM. The responses were later analyzed and understood, to help achieve the research goals of this research.

The second type of questions were the multiple-choice questions in which the respondents were able to choose more than one answer to answer the questions. The questions that were asked in the survey were used to identify in which industries do the survey respondents belong to. Understanding the industries that the respondents operate in can give helpful information, when analysing what types of blockchain applications are used, if used. Another similar styled question in this survey asked was used to identify which stakeholders in the organization's supply chain are usually contacted to give them the new information when undergoing ECM. This question was used to gain an insight on how information is communicated in the real world when going through ECM.

Finally, the third type of questions formulated in the survey were the text questions. These types of question were the highest number of questions of asked in the survey. The first text-based question in the survey was used to know what were the names of the organizations that the respondents work in. Next questions asked in this style was to determine if the organizations have used blockchain technologies in the past and in what ways, also if they have any future projects under research and development that they would like to implement blockchain technologies in, and which type of blockchain technology applications will they be using in those projects. The other type of text questions used in the survey were more focused on ECM, rather than blockchain technology. The survey participants were asked to describe what failures usually occur when there is a lack of correct communication between different departments in the organization's supply chain. This question's aim was to receive better understanding of the role of communication in a supply chain as well as its importance from the respondents. The final text questions asked were used to determine what challenges

organizations usually face when undergoing ECM and how do they usually respond to recover from such changes in their supply chain. Recognizing the usual problems these organizations face in a real-world scenario were needed to be better aware of ECM's challenges and what traditional methods are usually undertaken to recover and resist disturbances to the supply chain when going through ECM.

4.2 Research Analysis and findings

The survey was sent out online for a week, the responses were later collected, and some interesting findings have been noticed from the participant's responses. This section will analyse the statistical characteristics and differences between participant's answers. It is crucial to create an analysis for the survey to represent the results from this research and be able to create a conclusion.

Table 1 shows a detailed overview of the statistical familiarity of the survey participants with the use of blockchain technology in supply chain applications. It was noticed that most of the participants are moderately familiar with blockchain technology in a supply chain with a percentage of 35.3%. Then the second most amount of participants percentage are either slightly familiar or not all with blockchain technology in a supply chain with the percentage of the participants both being 23.5%. However, a small percentage of 11.8% of the survey participants have answered that they are very familiar with the application. Finally, with the lowest percentage of participants have answered extremely familiar with only 5.9% can claim that they are experts with blockchain technology in supply chain.

Table 1: Percentage of participants familiar with blockchain technology in a supply chain

Familiairty with Blockchain Technology	Percenatge of respondents
Not at all	23.5%
Slightly Familiar	23.5%
Moderately	35.3%
Very familiar	11.8%
Extremely familiar	5.9%

Table 2 shows the percentage of how often the survey's participants' organizations go through changes to develop their products. Most participants have answered either once a year or once every 2-3 years with a percentage of 26.5% for both. The third most answered answer with a percentage of 23.5% of the participants go through changes for

product development was once every 3+ years. Then 17.6% of the participants claim that their organizations go through change cycles 3+ times a year. Lastly the lowest percentage was two product development change cycles with a percentage of 5.9%.

Table 2: Percentage of how often participants go through change cycles for product development

Change Cycles for Product Development	Percentage of respondents
Once every 3+ years	23.5%
Once every 2-3 years	26.5%
Once a year	26.5%
Twice a year	5.9%
3+ times a year	17.6%

Looking at table 3 it shows, which industries, do all the participants in the survey belong to. The highest number shown in the survey of participants have come from the consultation industry, there were 10 respondents that are connected to that industry. Next, the industry with the second highest number of participants, 5, with half of the consultancy industry, have come from the computer and technology industry. The final notable number of participants that belong to an industry was shown to be the number 4, with three different industries having that many participants connected to them. The industries with 4 participants were the construction, energy, and manufacturing industry.

Table 3: Number of participants belonging to which industries

Industry	Number of respondents
Computer & Technology	5
Construction	4
Consulting	10
Education	1
Energy	4
Fashion	1
Finance & Economic	2
Government	1
Healthcare	2
Hospitality	1
Manufacturing	4
Nutrition	1
Services	1
Steel	1
Telecommunication	1
Transportation	2

The final table presented is the table 4, this table shows which stakeholders do the participants contact when there is ECM. Most of the respondents chose to contact the management and customers, when going through engineering with 24 and 22 votes respectively. Next, we have the employees and the suppliers with 17 and 16 respectively. Finally, the least chosen stakeholders were the manufacturers, 3rd party logistics, retail/sales department, and the partners which is the least from them all.

Table 4: Which stakeholders did the participants choose to contact when there is ECM

Stakeholders	Number of respondents
Customers	22
Employees	17
Management	24
Manufacturers	10
Partners	2
Retail/Sales Department	8
Suppliers	16
3rd Party Logistics	9

The participants were later asked if they have ever used any blockchain technology in their supply chain in any previous project and then asked if they have any new projects under research & development that will use blockchain applications. Most common answers were that most organizations that participated do not use blockchain technology or have it under research & development. Looking back at one of the previous questions regarding the familiarity with blockchain technology. It was noticed that most of the participants are not very familiar with it, so it does make sense that they do not use it. On the other, a few respondents have stated ways that they have previously used blockchain technology, especially for online payments. More respondents have answered ways they would have blockchain for research and development, they are currently researching ways of utilizing blockchain technology in tracking their products to reduce waste, improving their cybersecurity, using it for payments, and finally trying to utilize it to reach environmental goals and becoming more sustainable.

The next question on the survey asked the participants to explain any drawbacks and failures they go through due to lack of correct communication. A lot of respondents have claimed that they do, and this mainly causes a few obstacles on the way, such as confusion, delays, and a few mistakes. Correct communication seemed to be a challenge that every industry faces when going through ECM, a simple solution could help minimize this.

The respondents were then asked what additional challenges they may face, when going through an ECM process. The respondents have again stated that communication between stakeholders is a major challenge that is always faced. In addition to not having good training when the changes are happening, nor clearly understanding their roles. Other challenges faced would be, lack of agility, delays, and time wasted when communicating, accepting, and understand the changes. Of course, unexpected situations and complications always happen as well.

The final question asked in the survey was to describe how they would usually recover from such complications and challenges that they have previously mentioned. A lot of the participants would invest in training and extend project durations in order to correct them. Additionally, a few respondents have stated that they just need more communication, which could lead to more time loss. Other respondents have mentioned that they use market analysis techniques and try to plan better in the future. Lastly, a few respondents have stated that their organizations, do not usually try to respond to such issues and they would just ignore them or solve them in scrums.

4.3 Discussion

The main objective of this research was to understand the role of blockchain technology in today's market, as well as getting descriptions and insight about what happens during an ECM from individuals who often experience changes. Through literature review, the mentioned concepts were widely addressed, by exploring the definitions, drivers, and challenges of an engineering change management in addition to blockchain technology. In a bid to understand such topics a research survey was created, and interesting findings have been noticed when looking at the results received from the participants in this survey.

A crucial eye-opener recognized was the lack of use and implementation of blockchain technology by organizations in today's market. However, more and more organizations have started to have blockchain technology applications under research and development (Appendix 3). This means that more organizations will be shifting closer to entering industry 4.0 and using its applications. Yet it is first important for them to understand and gain knowledge and experience when utilizing blockchain technology applications. Especially when as recognized from the survey that most individuals lack the

knowledge and are not very familiar with the use of blockchain technology in supply chains (Appendix 2).

Based on the analysis of the communication and information flow in an organization it could be noticed that the main two people contacted once an organization goes through changes are both the customers and the management. Information being passed along to the management would later be passed along to other stakeholders in the organization's supply chain. This shows that the management act as middlemen in the project and information must be passed to them before being passed along to other departments. Which as previously mentioned in the literature review, the constant passing of information can often cause delays and misunderstanding between stake holders.

This hyporesearch was later demonstrated with evidence when the respondents were asked to mention what complications and challenges, they face as a result from failure in good communication. The responses were portrayed and have proved that communication is very important, and it is difficult to maintain. This brings us to the question that could blockchain technology, help in minimizing this problem in the supply chain, with its security, transparency, and traceability (Appendix 4).

The other challenges that organizations go through when undergoing ECM were mentioned and they were also similar to what was previously discussed and researched in the literature review. Which were the acceptance, resistance, and adaptation to changes. Additionally, confusion and lack of awareness on the new changes in the organization's supply chain can cause disruptions and waste time (Appendix 5).

The traditional responses that most organization have mentioned to tackle such challenges when undergoing ECM. Are investing and finding the correct training programs to adapt employees to such changes. As well as trying to analyze the market and becoming aware of changes by planning for the future and finally, by trying to improve communication between stakeholders. The following seem to be good solutions, however, could applying blockchains be able to make it easier and faster to implement those strategies (Appendix 6).

5 Conclusion

5.1 Limitations

However, every piece of technology has its own drawbacks and disadvantages when being implemented and used, blockchain technology is no different. Blockchain

technology has its own special features that make it unique, and this comes with a few faults and difficulties to face when implementing it. Of course, there are reasons and further research in developing this technology for future applications.

The blockchain offers a limited storage capacity since it must keep a full record of all blocks and operations throughout the entire blockchain network including its members. Whereas the event records itself may be destroyed at some time, the blockchain will continue to develop[91]. Despite that certain blockchain activities can help in sustaining the environment, a traditional blockchain is inefficient and can cause high energy consumption, as it is still not a mature technology and has a long way to go to become standardized[92]. Other limitations and disadvantages may include the very high complexity for blockchains, as it contains a very large network size, that makes it more difficult to adapt in a supply chain[93]. Additionally, they have a very strong security system that has private keys and if lost, it may never be able to recover them. This is also another reason as to why many businesses fail to utilize them in their operations[94].

When reviewing this course of research, a few limitations in this research may be found including some found in the survey and modeling. That can include the low number of survey participants as well as the limited time to conduct the survey about blockchain technology applications in a supply chain. This may have caused imprecise findings about the data found in the market. Additionally, a very limited amount of case studies about companies implementing blockchain technology in engineering change management application have been found. This caused difficulties in finding researching such scenarios and coming to conclusions. Finally, a limitation that can be found in this course of research, was in the creation of the models found in figures 6 & 7. As the supply chain is not very accurate, only a simple model was created which only involved and explained the key stakeholders and processes. A real supply chain is far more complex and complicated, as more departments are involved, and more complications can be found.

5.2 Summary

The main aim of this research was to understand the challenges that are faced in a modern supply chenin when it undergoes Engineering Change Management, as well as to further analyze the difficulties and propose new solution for the organization’s supply chain, using modern technology such as industry 4.0 applications. The main application focused on in this research was the blockchain technology.

In the literature review, the first topic that was focused on was industry 4.0. Clearly defined applications of this industry were explained, as well as all the features this industry offers compared to all the previous ones. The next topic was defining what blockchain technologies were, as well as explaining their special characteristics and benefits. Later on, the modern supply chains were explained, including the effects that blockchain technology may have in them. Finally, a few case studies of famous organizations using blockchain technologies and substitutes were further described, in addition as to how these applications could help solve modern challenges faced in ECM.

Next, for the methodology, two models were created and analyzed. The first model represented a simple workflow of how information flow in a modern supply chain looks like, as well as giving explanations to key processes that happen when passing the information in almost every supply chain. The second model created was very similar, it also showed a simple workflow of how information flows in a modern supply chain, but with a special feature, blockchain technology. Both models were analysed and the results from the analysis were then further explained.

Finally, a simple online survey was carried out and sent out online, for particular and experienced individuals, to help in understanding the markets knowledge on blockchain technology as well as understanding what happens when there's ECM. The research design was described, as well as the target of this course of research. The findings were simplified and studied to help in clarifying the subjects of matter and creating conclusions for the study of this research.

5.3 Implications for future research

This research can serve as an initial attempt in understanding the effects that blockchain technology can have on ECM. It has addressed a needed research gap for this concept, nevertheless, further examination and analysis are required. Future research can develop and build upon the current theories. Investigating the impacts of blockchain technology in ECM can be done on a much a larger scale, once blockchain technologies have reached their full potential and are fully developed. Additionally, once organizations start utilizing more systems made out of blockchain technology, their effectiveness can be further analyzed, and more conclusions can be created. In addition, this research only focused on the key stakeholders in a supply chain. However, there are many more different stakeholders and departments that make up a supply chain, especially in this

modern world where supply chains are becoming more complex. Finally, only a limited number of blockchain technology applications were stated in this research, although many more blockchain technologies exist around the world, and are frequently becoming further developed.

5.4 Implications for future practice

This research has created some new hypo research regarding blockchain technology. It can inspire businesses in understanding the impacts that blockchain technology has on their supply chain. In addition, it could show a new solution for organizations that face complications when going through engineering change management. Especially when a lot of organizations are struggling when facing communication failures. It also makes organizations more aware when entering the new industry 4.0 and gives them insights about how their supply chain can shape up.

6 References

1. Abiodun, T. P., Nwulu, N. & Olukanmi, P. Pioneering Emission Trading in Africa: An Architectural Design of a Blockchain-Powered Carbon Trading System. *J. Br. Blockchain Assoc.* **7**, 1–10 (2024).
2. Aghamohammadzadeh, E. & Fatahi Valilai, O. A novel cloud manufacturing service composition platform enabled by Blockchain technology. *Int. J. Prod. Res.* **58**, 5280–5298 (2020).
3. Riviere, A., DaCunha, C. & Tollenaere, M. Performances in Engineering Changes Management. in *Recent Advances in Integrated Design and Manufacturing in Mechanical Engineering* (eds Gogu, G., Coutellier, D., Chedmail, P. & Ray, P.) 369–378 (Springer Netherlands, Dordrecht, 2003). doi:10.1007/978-94-017-0161-7_36.
4. SAP Library - Engineering Change Management (LO-ECH). http://saphelp.ucc.ovgu.de/NW750/EN/da/6cb953495bb44ce10000000a174cb4/frameset.htm.
5. 5 Best Practices to Improve Engineering Change Management | PTC. https://www.ptc.com/en/blogs/cad/5-best-practices-to-follow-to-improve-engineering-change-management.
6. Houshmand, M. & Valilai, O. F. LAYMOD: a layered and modular platform for CAx product data integration based on the modular architecture of the standard for exchange of product data. *Int. J. Comput. Integr. Manuf.* **25**, 473–487; http://dx.doi.org/10.1080/0951192X.2011.646308 (2012).
7. Akhavan Hariri, M., Khashkhashimoghadam, S. & Fatahi Valilai, O. A Multi-product Sustainable Scheduling Model Focusing on Logistic Service Sharing in Cloud Manufacturing Systems. *Process Integr. Optim. Sustain.* https://doi.org/10.1007/s41660-025-00532-9 (2025) doi:10.1007/s41660-025-00532-9.
8. What Is Engineering Change Management? *PLM Tech Talk Blog* https://plmtechtalk.com/2021/04/20/what-is-engineering-change-management/ (2021).
9. Kadam, O. B., Pirayesh, A. & Fatahi Valilai, O. Technological Insights of Interoperable Models for Integration of CAD/PLM/PDM and ERP Modules in Engineering Change Management. in *Flexible Automation and Intelligent Manufacturing: The Human-Data-Technology Nexus* (eds Kim, K.-Y., Monplaisir, L. & Rickli, J.) 556–564 (Springer International Publishing, Cham, 2023). doi:10.1007/978-3-031-17629-6_58.

10. Engineering Change Management: 10 Steps to Transformation. *The Change Management Blog* https://change.walkme.com/engineering-change-management/ (2018).
11. Engineering Change Management. *Aligni* https://docs.aligni.com/engineering-change-management/.
12. Change Management Guide: The Process, Challenges & Benefits. *ARES PRISM* https://www.aresprism.com/guides/change-management-guide-the-process-challenges-benefits/ (2020).
13. Houshmand, M. & Valilai, O. F. A layered and modular platform to enable distributed CAx collaboration and support product data integration based on STEP standard. *Int. J. Comput. Integr. Manuf.* **26**, 731–750 (2013).
14. Zaringhalam, S., Khalilzadeh, M. & Fatahi Valilai, O. An integrated framework for collaborative product design and assembly based on STEP compatible ontology model in cloud manufacturing. *Discov. Appl. Sci.* **7**, 37 (2024).
15. Managing change and release | McKinsey. https://www.mckinsey.com/business-functions/operations/our-insights/managing-change-and-release.
16. Elezi, F., Maier, T. G. & Lindemann, U. Engineering change management challenges and management cybernetics. in *2013 IEEE International Systems Conference (SysCon)* 567–573 (2013). doi:10.1109/SysCon.2013.6549938.
17. Collaborative Engineering: Opportunities and Challenges. https://www.hynesindustries.com/blog/collaborative-engineering-opportunities-and-challenges.
18. Tools and approach to succeed with product complexity management. *Implement Consulting Group* https://implementconsultinggroup.com/article/product-complexity-management/.
19. Industrial Revolution | Definition, History, Dates, Summary, & Facts | Britannica. https://www.britannica.com/event/Industrial-Revolution.
20. Causes of the Industrial Revolution. *HISTORY CRUNCH - History Articles, Biographies, Infographics, Resources and More* https://www.historycrunch.com/causes-of-the-industrial-revolution.html.
21. Society, N. G. The Industrial Revolution. http://www.nationalgeographic.org/topics/resource-library-industrial-revolution/.
22. Zeynivand, M., Ranjbar, H., Radmanesh, S.-A. & Fatahi Valilai, O. Alternative process routing and consolidated production-distribution planning with a destination oriented strategy in cloud manufacturing. *Int. J. Comput. Integr. Manuf.* **34**, 1162–1176 (2021).
23. The Industrial Revolution - from Industry 1.0 to Industry 4.0. *DiConnex* https://diconnex.com/en/blog/2020/06/23/the-industrial-revolution/ (2020).
24. The Industrial Revolution from Industry 1.0 to 5.0! *Supply Chain Game Changer™* https://supplychaingamechanger.com/the-industrial-revolution-from-industry-1-0-to-industry-5-0/ (2022).
25. Industrial Revolution - From Industry 1.0 to Industry 4.0. https://www.desouttertools.com/industry-4-0/news/503/industrial-revolution-from-industry-1-0-to-industry-4-0.
26. What is Industry 4.0 and how does it work? | IBM. https://www.ibm.com/topics/industry-4-0.
27. Fourth Industrial Revolution. *World Economic Forum* https://www.weforum.org/focus/fourth-industrial-revolution/.
28. Gaspar, M. & Juliao, J. Impacts of Industry 4.0 on Operations Management: Challenges for Operations Strategy. in *2021 The 8th International Conference on Industrial Engineering and Applications(Europe)* 57–61 (ACM, Barcelona Spain, 2021). doi:10.1145/3463858.3463900.
29. PricewaterhouseCoopers. 101: 1,2,3... Here comes the 4th Industrial Revolution. *PwC* https://www.pwc.com.au/digitalpulse/fourth-industrial-revolution-guide.html.
30. What Are the 4 Industrial Revolutions? *onupkeep* https://www.upkeep.com/learning/four-industrial-revolutions.

31. Industry 4.0 and the fourth industrial revolution explained. *i-SCOOP* https://www.i-scoop.eu/industry-4-0/.
32. What is industry 4.0? | Definition, technologies, benefits | SAP Insights. *SAP* https://www.sap.com/insights/what-is-industry-4-0.html.
33. Sachdev, M. The Role of Big Data Analytics in Industry 4.0. https://blog.rgbsi.com/big-data-analytics-in-industry-4.0.
34. Cyber Security Principles | Cyber.gov.au. https://www.cyber.gov.au/acsc/view-all-content/advice/cyber-security-principles.
35. What is Industry IoT (4.0)? *CMSC* http://www.cms-connected.com/PromoNews/What-is-Industry-IoT-4-0.
36. de Paula Ferreira, W., Armellini, F. & De Santa-Eulalia, L. A. Simulation in industry 4.0: A state-of-the-art review. *Comput. Ind. Eng.* **149**, 106868 (2020).
37. Masood, T. & Egger, J. Augmented reality in support of Industry 4.0—Implementation challenges and success factors. *Robot. Comput.-Integr. Manuf.* **58**, 181–195 (2019).
38. Kovács, G., Benotsmane, R. & Dudás, L. THE CONCEPT OF AUTONOMOUS SYSTEMS IN INDUSTRY 4.0. *Adv. Logist. Syst. - Theory Pract.* **12**, 77–87 (2019).
39. Essien, N. P., Okon, U.-A. & Frank, P. A. System integration for Industry 4.0. *Nine Pillars Technol. Ind. 40* 215–231 (2020) doi:10.1049/PBTE088E_ch11.
40. Additive Manufacturing in Industry 4.0. https://www.esa-automation.com/en/additive-manufacturing-in-industry-4-0/ (2020).
41. Industry 4.0, Cloud Computing, Smart Factory, Internet of Things (IoT). *Headland Machinery* https://www.headland.com.au/industry-4-0-cheat-sheet-industry4-0-cloud-computing-smart-factory-internet-of-things/ (2017).
42. The Fourth Industrial Revolution: Cloud Computing and Cybersecurity. *Taylored Systems | Indianapolis* https://www.taylored.com/blog/the-fourth-industrial-revolution-cloud-computing-and-cybersecurity/ (2019).
43. Blockchain technology applications for Industry 4.0: A literature-based review | Elsevier Enhanced Reader. https://reader.elsevier.com/reader/sd/pii/S2096720921000221?token=B2B5B7ECE8F2371195499BEF8BFBEB51379C559478F00B0D0B447F0540E162C28215AF0556EF5C9ABF14A70507066141&originRegion=eu-west-1&originCreation=20220511003823 doi:10.1016/j.bcra.2021.100027.
44. Jha, V. Blockchain technology applications for Industry 4.0. https://www.itechupdates.com/blockchain-technology-industry-4-0/ (2022).
45. Ahmadi, E., Khaturia, R., Sahraei, P., Niyayesh, M. & Valilai, O. F. Using Blockchain Technology to Extend the Vendor Managed Inventory for Sustainability. *Int. J. Ind. Manuf. Eng.* **15**, 5 (2021).
46. Ganesan, S., Wicaksono, H. & Fatahi Valilai, O. Enhancing Vendor Managed Inventory with the Application of Blockchain Technology. in *Advances in System-Integrated Intelligence* (eds Valle, M. et al.) 262–275 (Springer International Publishing, Cham, 2023).
47. Blockchain Explained. *Investopedia* https://www.investopedia.com/terms/b/blockchain.asp.
48. Blockchain: What it is and How it Works. *NerdWallet* https://www.nerdwallet.com/article/investing/blockchain.
49. Mohamed, N. & Al-Jaroodi, J. Applying Blockchain in Industry 4.0 Applications. in *2019 IEEE 9th Annual Computing and Communication Workshop and Conference (CCWC)* 0852–0858 (2019). doi:10.1109/CCWC.2019.8666558.
50. Mofatteh, M. Y., Pirayesh, A. & Fatahi Valilai, O. Energy Semantic Data Management and Utilization in Smart Grid Networks with Focus on Circular Economy. in *Handbook of Smart Energy Systems* (eds Fathi, M., Zio, E. & Pardalos, P. M.) 1–24 (Springer International Publishing, Cham, 2022). doi:10.1007/978-3-030-72322-4_162-1.
51. Mofatteh, M. Y. *et al.* Traceability in Fast-Moving Consumer Goods Industries by Application of Blockchain Technology and Smart Contracts. in *Human Interaction & Emerging Technologies (IHIET 2023): Artificial Intelligence & Future Applications* vol. 0 (AHFE Open Acces, 2023).

52. PricewaterhouseCoopers. How can blockchain power industrial manufacturing? *PwC* https://www.pwc.com/us/en/industries/industrial-products/library/blockchain-industrial-manufacturing.html.
53. Blockchain technology for supply chains--A must or a maybe? | McKinsey. https://www.mckinsey.com/business-functions/operations/our-insights/blockchain-technology-for-supply-chainsa-must-or-a-maybe.
54. Blockchain technology. *BaFin* https://www.bafin.de/EN/Aufsicht/FinTech/Blockchain/blockchain_node_en.html.
55. Farajzadeh, F., Moadab, A., Fatahi Valilai, O. & Houshmand, M. A Novel Mathematical Model for a Cloud-Based Drone Enabled Vehicle Routing Problem considering Multi-Echelon Supply Chain. *21st IFAC World Congr.* **53**, 15035–15040 (2020).
56. Moadab, A., Farajzadeh, F. & Fatahi Valilai, O. Drone routing problem model for last-mile delivery using the public transportation capacity as moving charging stations. *Sci. Rep.* **12**, 6361 (2022).
57. How Supply Chains Work. *Investopedia* https://www.investopedia.com/terms/s/supplychain.asp.
58. Higgins, M. Council Post: Blockchain In Supply Chain. *Forbes* https://www.forbes.com/sites/forbestechcouncil/2021/11/08/blockchain-in-supply-chain/.
59. Using Blockchain to Drive Supply Chain Transparency and Innovation. *Deloitte United States* https://www2.deloitte.com/us/en/pages/operations/articles/blockchain-supply-chain-innovation.html.
60. Building resilient supply chains with blockchain. 10 (2020).
61. Michelman, P. Building a Resilient Supply Chain. *Harvard Business Review* (2007).
62. What is a resilient supply chain? | agility and risk management | SAP Insights. *SAP* https://www.sap.com/insights/what-is-a-resilient-supply-chain.html.
63. Rezapour Niari, M., Eshghi, K. & Fatahi Valilai, O. Using cloud manufacturing to establish an ecosystem network for COVID-19 ventilator production. *Int. J. Comput. Integr. Manuf.* **36**, 842–862 (2023).
64. Rezapour Niari, M., Eshgi, K. & Fatahi Valilai, O. Topology analysis of manufacturing service supply–demand hyper-network considering QoS properties in the cloud manufacturing system. *Robot. Comput.-Integr. Manuf.* **72**, 102205 (2021).
65. Blockchain technology for enhancing supply chain resilience | Request PDF. *ResearchGate* https://doi.org/10.1016/j.bushor.2018.08.012 doi:10.1016/j.bushor.2018.08.012.
66. NetSuite.com. Creating a Sustainable Supply Chain. *Oracle NetSuite* https://www.netsuite.com/portal/resource/articles/erp/supply-chain-sustainability.shtml.
67. Niari, M. R., Eshghi, K. & Valilai, O. F. Adaptive capacity management in cloud manufacturing hyper-network platform: Case of COVID-19 equipment production. *Int. J. Manag. Sci. Eng. Manag.* **17**, 239–258 (2022).
68. Mohammadian, N., Fatahi Valilai, O. & Schlüter, A. Sustainable design and repair: Leveraging circular economy and machine learning for product development. *J. Open Innov. Technol. Mark. Complex.* **11**, 100469 (2025).
69. Ten benefits blockchain brings to supply chains. https://supplychaindigital.com/digital-supply-chain/ten-benefits-blockchain-brings-to-supply-chains (2022).
70. Key Use Cases and Benefits of Blockchain in Supply Chain Management. *101 Blockchains* https://101blockchains.com/benefits-of-blockchain-in-supply-chain-management/ (2021).
71. Mofatteh, M. Y. *et al.* A Smart Adaptive Transportation Planning Model Including Real-time Drivers' Knowledge using Answer Set Programming and Knowledge Graphs. *Procedia Comput. Sci.* **253**, 2358–2368 (2025).
72. Mofatteh, M. Y., Kumar, V., Ramachandra Krishnamoorthy, N. & Fatahi Valilai, O. APPLICATION OF BLOCKCHAIN TECHNOLOGY AND IOT FOR SUSTAINABLE SUPPLY CHAIN MODELS: 50th International Conference on Computers and Industrial Engineering: Sustainable Digital Transformation, CIE 2023. *50th Int. Conf. Comput. Ind. Eng. CIE 2023* 733–744 (2023).

73. BMW announces PartChain supply blockchain for tracking automotive parts. *SiliconANGLE* https://siliconangle.com/2020/04/01/bmw-announces-partchain-supply-chain-blockchain-tracking-automotive-parts/ (2020).
74. BMW Group uses Blockchain to drive supply chain transparency. https://www.press.bmwgroup.com/global/article/detail/T0307164EN/bmw-group-uses-blockchain-to-drive-supply-chain-transparency?language=en.
75. BMW uses a blockchain for deliveries of spare parts. Will transfer all suppliers to the platform. *TAdviser.ru* https://tadviser.com/index.php/Product:PartChain_(blockchain_platform).
76. BMW Takes a Turn towards the Blockchain for Industrial Traceability. *Cointribune* https://www.cointribune.com/en/blockchain-en/traceability/bmw-takes-a-turn-towards-the-blockchain-for-industrial-traceability/ (2021).
77. Automation, I. BMW Group uses Blockchain to drive supply chain transparency. *Industrial Automation Magazine* https://industrialautomationindia.in/newsitm/9439/BMW-Group-uses-Blockchain-to-drive-supply-chain-transparency/news.
78. Open Industry 4.0 Alliance. *Open Industry 4.0 Alliance* https://openindustry4.com/.
79. Benefits of Blockchain in E-commerce Blog - Read now! *Swisslog* https://www.swisslog.com/en-us/case-studies-and-resources/blog/benefits-of-blockchain-in-e-commerce.
80. What are RFID Tags? Learn How RFID Tags Work, What They're Used for, and Some of the Disadvantages of RFID Technology. *Camcode* https://www.camcode.com/blog/what-are-rfid-tags/ (2017).
81. RFID technology in matrix production. *KUKA AG* https://www.kuka.com/en-de/industries/solutions-database/2018/05/solutions-automotive-rfid-tec.
82. Gerdau and RHI Magnesita using blockchain to enhance performance at mill. https://www.steelorbis.com/steel-news/latest-news/gerdau-and-rhi-magnesita-using-blockchain-to-enhance-performance-at-mill-1205702.htm.
83. Gerdau, RHI adopt blockchain for contracts. *Davis Index - Daily metal prices, scrap prices & global metal market* https://www.davisindex.com/ (2021).
84. RHI Magnesita and Gerdau leading the way in using Blockchain in the steel industry. *RHI Magnesita* https://www.rhimagnesita.com/de/rhi-magnesita-and-gerdau-leading-the-way-in-using-blockchain-in-the-steel-industry/ (2021).
85. Miles, T. Gerdau and RHI Magnesita launch pioneering solution for steel trading in blockchain. *Bulletin Bits* https://bulletinbits.com/gerdau-and-rhi-magnesita-launch-pioneering-solution-for-steel-trading-in-blockchain/ (2021).
86. Samsung | History & Facts | Britannica. https://www.britannica.com/topic/Samsung-Electronics.
87. Samsung Blockchain | Apps. *The Official Samsung Galaxy Site* https://www.samsung.com/global/galaxy/apps/samsung-blockchain/.
88. Samsung Blockchain. *Samsung Developers* https://developer.samsung.com/SamsungBlockchain/keystore/keystore/overview.html.
89. Online Surveys: What are they, advantages & examples. *QuestionPro* https://www.questionpro.com/blog/what-are-online-surveys/ (2018).
90. Likert Scale Surveys—Definitions, Examples & How-tos. *Typeform* https://www.typeform.com/surveys/likert-scale-questionnaires/.
91. Bischoff, O. & Seuring, S. Opportunities and limitations of public blockchain-based supply chain traceability. *Mod. Supply Chain Res. Appl.* **3**, 226–243 (2021).
92. Top Disadvantages of Blockchain Technology. *101 Blockchains* https://101blockchains.com/disadvantages-of-blockchain/ (2020).
93. Smith, T. L. The 6 Limitations of Blockchain Technology. *Everything Blockchain* https://medium.com/everything-blockchain/the-6-limitations-of-blockchain-technology-2d1b686c0293 (2018).

94. Advantages and disadvantages of Blockchain. *BBVA.CH* https://www.bbva.ch/en/news/advantages-and-disadvantages-of-blockchain/.

Appendix 1

Online Survey

Industry 4.0 solution for Engineering

Change Management using Blockchain Technology

This survey is part of the researchers' research research: We will be studying the influences blockchain technology might have when going through engineering change management.

Participation

-Your participation in this survey is voluntary. You may refuse to take part in the research or exit the survey at any time without penalty. You are free to decline to answer any particular question you do not wish to answer for any reason.

-Your survey answers will be stored in Google Forms only accessible by the researcher Ahmad Bashaireh and Dr. Omid Fatahi Valilai, until data collection has closed. Microsoft Forms only collects email address, but your names will not be mentioned in our report. No one will be able to identify you or your answers, and no one will know whether or not you participated in the study.

Informed Consent

Clicking on the « You have my consent » button indicates that:

-You have read the above information
-You voluntarily agree to participate
-You agree with the use and analysis of the answers you provide

If you choose not to participate in the study, I would like to thank you for your time, and you may close this survey.

1.I have read all the information above and: Required to answer. (Single choice.)
O You have my consent.

2.Please state your organisation's name. Required to answer. (Single line text.)
Enter your answer

3.Please state the industry in which your organisation belongs to. Required to answer. (Multiple choice)

- Advertising / Marketing
- Aerospace

- Agriculture
- Computer & Technology
- Construction
- Consulting
- Education
- Energy
- Entertainment
- Fashion
- Finance & Economic
- Food & Beverages
- Government
- Hospitality
- Manufacturing
- Media & News
- Mining
- Pharmacueticals
- Services
- Telecommunication
- Transportation

4.How familiar are you with blockchain technology applications in change management? Required to answer. (Likert.)

	Not at all (1)	Slightly Familiar (2)	Moderately (3)	Very Familiar (4)	Extremely Familiar (5)
Familiarity	O	O	O	O	O

5.Have you ever used blockchain technology in any previous project? If so, kindly give a short description about how its involvement influenced the project. Required to answer. (Multi-line text)

Enter your answer

6.Do you have any blockchain projects under research & development? If so, which applications of blockchain technology will you be using? Required to answer. (Multi-line text)

Enter your answer

7.How often does your organsation go through changes for product development? Required to answer. (Likert.)

	Once every 3+ years	Once every 2-3 years	Once a year	Twice a year	3+ times a year
Change Cycles	O	O	O	O	O

8.Which Stakeholders are contacted when changes are made to the supply chain? Required to answer. (Multiple choice)

- Customer
- Employees
- Management
- Manufacturers
- Retail/Sales Department
- Suppliers
- 3rd party Logistics
- Other

9.Were there any failures caused due to the lack of correct communication between stakeholders when going through change management, and if so kindly explain further? Required to answer (Multi-line text)

Enter your answer

10.What other challenges does your organization face when there is engineering change management? Required to answer. (Multi-line text)

Enter your answer

11.How does your organisation usually respond and tackle these challenges? Required to answer. (Multi-line text)

Enter your answer

12.Is there any additional information you would like to add?

Enter your answer

Appendix 2

Have you ever used blockchain technology in any previous project? If so, kindly give a short description about how its involvement influenced the project.

34 responses34Responses

ID	Name	Responses
1	anonymous	Never
2	anonymous	Nothing
3	anonymous	No
4	anonymous	No

ID	Name	Responses
5	anonymous	No
6	anonymous	No
7	anonymous	Yes in renewal of passports
8	anonymous	Government services. NFTs
9	anonymous	No
10	anonymous	No
11	anonymous	No
12	anonymous	No
13	anonymous	No
14	anonymous	No
15	anonymous	No we didn’t
16	anonymous	no
17	anonymous	No
18	anonymous	points for flydubai, cryptocurrencies
19	anonymous	No
20	anonymous	Did not use, only crypto currency
21	anonymous	No
22	anonymous	Not yet
23	anonymous	No
24	anonymous	No
25	anonymous	I have not.
26	anonymous	We only had a research project on using Blockchain in Supply Chain Management
27	anonymous	Many use cases mainly in government and Oil & Gas industries.
28	anonymous	-
29	anonymous	No

ID	Name	Responses
30	anonymous	None
31	anonymous	responsible for go to market activity of projects
32	anonymous	Not yet, however, we are in the process of utilizing Blockchain as it's requested by multiple clients due to the security level and immutability.
33	anonymous	No
34	anonymous	Yes

Appendix 3

Do you have any blockchain projects under research & development? If so, which applications of blockchain technology will you be using?

34 responses34Responses

ID	Name	Responses
1	anonymous	None
2	anonymous	None
3	anonymous	No
4	anonymous	No
5	anonymous	No
6	anonymous	No
7	anonymous	No
8	anonymous	Trade Finance Applications. Banking payments.
9	anonymous	No
10	anonymous	No
11	anonymous	No
12	anonymous	No
13	anonymous	No
14	anonymous	No
15	anonymous	No
16	anonymous	no

ID	Name	Responses
17	anonymous	No
18	anonymous	Digital twin, Ethereum
19	anonymous	Im searching on the impact of blockchain tech on business environments and the opportunities and threats that it offer to the businesses generally .
20	anonymous	Crypto currency
21	anonymous	Use in digital asset records management.
22	anonymous	Yes Under implementation: Access Control and security Under evaluation: Supply Chain and logistics for the aircraft maintenance items
23	anonymous	No
24	anonymous	Yes
25	anonymous	I don't.
26	anonymous	Application of private blockchain in Supply Chain Management
27	anonymous	Personally doing mining. For business, again many use cases e.g In mining industry tracking mined products from source till it reaches the end user. Objective reduce waste (tighter control on mined goods).
28	anonymous	-
29	anonymous	No
30	anonymous	None
31	anonymous	Mainly payments aggregation and collection for issuers
32	anonymous	Yes, we are researching the application of Blockchain in supply chain area, utilizing origin trail.
33	anonymous	No
34	anonymous	No

Appendix 4

Were there any failures caused due to the lack of correct communication between stakeholders when going through change management, and if so kindly explain further?

34 responses34Responses

ID	Name	Responses
1	anonymous	None
2	anonymous	None
3	anonymous	Yes like in construction projects
4	anonymous	No
5	anonymous	No
6	anonymous	no
7	anonymous	Yes delays and mistakes
8	anonymous	Blockchain projects require significant efforts in stakeholder management to agree on process and data sharing details. This is normally the most complex parts.
9	anonymous	No
10	anonymous	No
11	anonymous	No
12	anonymous	Not clear question!!
13	anonymous	NA
14	anonymous	Yes, in one case we bought instruments to perform certain tests, but unfortunately the distributor was unable to honor our agreement to provide continuous supplies.
15	anonymous	Yes. It created confusion about what are we doing and why are we introducing the change. We introduced the change to enhance our competitive advantage, but some stakeholders thought that we were having financial difficulties
16	anonymous	no
17	anonymous	Yes it may happen sometimes dur wrong interpretation or lack of complete communication
18	anonymous	not clear roles and responsibilities resistance to change No SOD
19	anonymous	Yes there are a lot but Not serious failiures, for example recently the iran electricity management wanted a through yearly report from our powerplant, they could not get what they wanted becuase of management change. So after some month they called me and asked where are you guys!! And i informed the new managment that they need a

ID	Name	Responses
		report. If there was a correct form of cumiunication, we avoid lots of breakdowns. But i think the underlying problem is lack of responsibility.
20	anonymous	Several obstacles were encountered
21	anonymous	Incoorect or detailed Requirement documentation leads to failures which are fixed later.
22	anonymous	Sometimes it happenes and this could be related to the lack of the unified communication plan that is supposed to be set and planned at the beginning of the project
23	anonymous	None
24	anonymous	Incomprehensible and analytical reports
25	anonymous	Yes there were failures. I found that the authenticity of the decisions are challenged particularly when a stakeholder is not on board with the changes.
26	anonymous	That's the goal but lack of time and energy can lead to lack of communication and it becomes a vicious cycle!
27	anonymous	Yes. Poor integration within the organization creates communication issues.
28	anonymous	-
29	anonymous	No
30	anonymous	Our company is a small business, and decision makers are the 2 stakeholders. The communication is always open and clear.
31	anonymous	None all governed by SLAs
32	anonymous	Drawbacks are normal while working on huge projects, in this specific case, the project involves government entity (entities), manufacturers, distributors and consumption centers, therefore, having proper and open communication channels is a must, plan has to be mutually agreed on, and a steering committee from all parties shall be in place, accordingly, we managed to reduce conflicts and resistance, yet, we came across multiple opinions and points of view which dragged the project for longer period. My recommendation is to properly plan, communicate and execute the details as agreed.
33	anonymous	No clarity in understanding the requirements.
34	anonymous	No

Appendix 5

What other challenges does your organization face when there is engineering change management?

34 responses34Responses

ID	Name	Responses
1	anonymous	Internal communication Acceptance and adaptation Commitment Technology
2	anonymous	Unexpected situations
3	anonymous	Inter- disciplinary engineering mistakes
4	anonymous	1. Resistance by employees 2. Training. 3. Human resources
5	anonymous	Quality
6	anonymous	People resistance to change
7	anonymous	Changing the culture and the status that every one is used to
8	anonymous	Agreements on standards and data exchange requirements.
9	anonymous	Awareness and desire
10	anonymous	NA
11	anonymous	Nothing
12	anonymous	Provide option for the answers
13	anonymous	Na
14	anonymous	Culture change that requires better planning.
15	anonymous	The lack of a proper communication plan to explain the change
16	anonymous	lack of science and investment
17	anonymous	involvement of all parties
18	anonymous	not clear roles and responsibilities resistance to change No SOD
19	anonymous	We are a heavy duty indystry. So in times of chane over, all the systems with their defects should be handed over to new team. It is a hell of a job.
20	anonymous	Keeping the talent, develop people, reserve intellectual property
21	anonymous	Explained in point 9

ID	Name	Responses
22	anonymous	Adoption by the end user to the new process or technology. This is considered a major challenge that requires close monitoring during and after the implementation of the project
23	anonymous	Acceptance of change
24	anonymous	Staff training
25	anonymous	The fact that old practices and previously engineered products are trusted by time. Creating confidence in engineering changes is always a question.
26	anonymous	Enough and clear communication between operations and decicion makers (normally top management)
27	anonymous	Lack of agility, , politics between departments, sharing data between departments is always an issue and organization structure doesn't support the end to end blockchain project.
28	anonymous	-
29	anonymous	Main challenge with change management is usually resistance of the people towards accepting it
30	anonymous	Time required for new development and resources
31	anonymous	Challenges can be in communication and finding the right language for commercial to understand
32	anonymous	Usually, customers do not appreciate"change requests", and prefer to apply system changes under the support and maintenance.
33	anonymous	Resistance to change
34	anonymous	Qualifications

Appendix 6

How does your organisation usually respond and tackle these challenges?

34 responses34Responses

ID	Name	Responses
1	anonymous	Awareness and training Culture change Automation Involvement of people
2	anonymous	But better planning next time
3	anonymous	Lessons learnt. QAPA

ID	Name	Responses
4	anonymous	By extending the project duration gor more training and adaptation
5	anonymous	More testing
6	anonymous	communication using logic trees
7	anonymous	Corrective actions and more training
8	anonymous	Design Thinking Workshops to align objectives.
9	anonymous	Usually
10	anonymous	Correct the process
11	anonymous	Market analysis
12	anonymous	Provide option for the answers
13	anonymous	NA
14	anonymous	Apply change management tools, like communication, staff involvement in the role out and others.
15	anonymous	By trying to prepare a communication matrix
16	anonymous	gather some money from some investments and hire expert engineers
17	anonymous	Communication and communication
18	anonymous	yearly
19	anonymous	Just ignoring them.
20	anonymous	Task force, consultation, buying system
21	anonymous	Often resolved in Scrums.
22	anonymous	During the implementation there should be a change management program that covers the adoption of the end user with clear KPI's. A champion per stockholders/Business unit should be defined with clear mission and responsibilities to make sure all endusers are adopting to the new process or technology before going live. Second and as a post assessment, a technology health check should be conducted after 6months to 1 year from going live. This is needed to evaluate the level of adoption and their related KPI's
23	anonymous	Try to communicate with all stakeholders
24	anonymous	Ongoing training, and CRM enchantments

ID	Name	Responses
25	anonymous	Simulations and testing proved to tackle the challenge.
26	anonymous	Trying to propose new solutions or improve the current solution if possible.
27	anonymous	1. Creation of an empowered squad to represent each department. 2. Business to own and drive the project. IT can't be the project owner. 3. Focus on a tangible outcome/business outcome. 4. CXO sponsorship
28	anonymous	-
29	anonymous	We mainly educate and explain through sessions how and where the benefits will come to the people and the organization
30	anonymous	Utilize the existing resources for the optimum output Detailed technical study for the new development suitability for the existing systems upgrade, prior implementation
31	anonymous	After/ post launch process in place to assess
32	anonymous	Planning, weekly communication through single channel, agreed-on milestones, professional hand over at every single stage, and most importantly, management commitment.
33	anonymous	Conduct awareness sessions. engage change agents.
34	anonymous	Collaboration with reputable education institutions