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An Integrated Reverse Logistic Management Architecture for the Steel Industry

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***Résumé* – La gestion de la logistique amont et aval de la construction est intrinsèquement complexe et distribuée, tandis que l'internet des objets (IoT) et la blockchain sont reconnus comme des solutions prometteuses pour une gestion reposant sur l'information. En tirant les leçons des paradigmes IoT et Blockchain dans la littérature, cet article propose une architecture basée sur l'IoT en tant que paradigme Blockchain of Things (BCoT). Dans cette étude, nous avons cherché à comprendre l'impact du système de suivi IoT-blockchain proposé, sur la réduction des déchets et l'amélioration des processus de gestion de la chaîne d'approvisionnement des projets de charpente métallique. Pour atteindre cet objectif, nous avons mené une étude de cas sur la transformation numérique d'un processus de gestion logistique de l'acier dans un projet de construction au Québec, au Canada. Nous avons développé une architecture intelligente de fabrication d'acier basée sur l'IoT-blockchain et proposé une méthode de suivi d'identification automatisée pour le suivi des produits en acier. Enfin, nous avons discuté des impacts potentiels de l'architecture proposée sur trois aspects de la durabilité, appelés (a) aspects économiques, (b) environnementaux et (c) sociaux, dans les projets de charpente métallique.**

***Abstract* – Construction forward and reverse logistic management is inherently complex and distributed, while internet of things (IoTs) and blockchain are recognized as promising solutions for information-reliant management. By learning from the lessons of IoT and Blockchain paradigms in the literature, this paper proposes an IoT based architecture as a Blockchain of Things (BCoT) paradigm. In this study, we aimed to understand the impact of the proposed IoT-blockchain tracking system, on reducing waste and improving supply-chain management processes of structural steel projects. To achieve this goal, we conducted a case study on digital transformation of a steel logistics management processes in a construction project in Quebec, Canada. We developed a smart steel manufacturing IoT-blockchain based architecture and proposed an automated identification tracking method for tracking steel products. Finally, we discussed the potential impacts of the proposed architecture on three aspects of sustainability, known as (a) economic, (b) environmental, and (c) social aspects, in structural steel projects.**

***Mots clés* - Intégration, Gestion de projet, Chaîne d'approvisionnement, Blockchain, Internet des objets, IoT, BCoT, Logistique inverse, Construction.**
***Keywords* – Integration, Project management, Supply-chain, Blockchain, Internet of Things, IoT, BCoT, Reverse logistics, Construction.**

1 INTRODUCTION

The steel industry is a major part of the world economy and has a direct impact on the development of a country (Pourmehdi et al., 2022). Supply-chain management in construction projects, including structural steel projects, is demanding and complex in nature (Zhao et al., 2023). Large quantities of information are produced in steel manufacturing and construction supply-chain processes, which must be shared between various project partners. Studies show 80% of construction supply-chain problems occur due to the lack of flow of information (Ballard and Howell, 1994; Hall et al., 2022). This can be related to a variety of interrelated factors such as: lack of suitable technologies, multiple stakeholders with conflicts of interest, uncertainties in a changeable environment, outdated models and schedules, inefficient design strategies, and inefficient supply-chain management techniques (Daboun et al., 2022; Hall et al., 2022; Zhao et al., 2023). These factors ultimately affect the economic, environmental, and social aspects of managing projects. Consequently, addressing the existing challenges which hinder the efficiency and sustainability of the structural steel supply-chain systems is necessary (Oesterreich et al., 2016). This motivated the authors to propose an IoT architecture, which could support automated tracking of structural steel products. Based on a conceptual study, this paper proposes a multi-layer IoT-Blockchain based architecture for steel supply-chain management, through designing data collection, transmission, and analyzing web-based applications for forward and reverse logistics tracking of steel products. The proposed IoT architecture should be tested eventually in an empirical study. Finally, the impact of this digital procedure on sustainability (environmental, economic, and social) has been discussed.

2 BACKGROUND AND MOTIVATION

The increased awareness of the environmental, economic, and social aspects of operational activities in a competitive market of the construction industry, urged the need to achieve more sustainable supply-chain management practices (Gubbi et al., 2013; Nayeri et al., 2020). The more technology advances and more complex construction projects become, more advanced management strategies are required which can be adaptable to the changing environment. This motivated researchers and practitioners to conduct research and development activities on the integration of Industry 4.0 technologies and Reverse Logistics (RLs) techniques as part of their supply-chain management strategies (Zarbakhshnia et. al., 2019).

2.1 Reverse Logistics (RLs)

According to Pourmehdi et al (2022), reverse logistics (RLs), also known as closed-loop supply-chain, includes management practices which have positive impacts on sustainability. RLs refers to all operational activities that are related to the reuse of materials and products (Shahparvari et al., 2021). This includes the planning, implementation, and controlling the efficient stream of information and products from the user site to the origin point of fabrication for recovering their value, recycling, or disposal (Pourmehdi et al., 2022). The application of RLs techniques can boost sustainability and minimise the adverse environmental impacts through reusing end-of-life material. In addition, it provides economic and social benefits such as risk elimination and human-machine cooperation (Pourmehdi et al 2022).

2.2 Industry 4.0 technologies

The concept of I4.0 is comparatively new in the construction domain and a more precise outline is required for its proper application (Perrier et al., 2020; Pourmehdi et al 2022). I4.0 is described as technologies which integrate physical machinery and devices with network sensors and software, that are used to predict, control and plan for a new level of value chain organization and management across the product or project life cycle (Kagermann et al., 2013; Jaideep et al., 2017). The most studied application of I4.0 technologies in the construction literature are identified as information sharing, simulations, controlling project progress, and collaborative decision-making (Zhao et al., 2023). In logistics and sustainable supply-chain management, the literature identified various benefits of I4.0 and explored its opportunities such as cost and schedule savings due to material and operational competencies improvements, enhanced resource utilisation, and advanced information sharing to improve forecast accuracy and reduce waste generation (Dalenogare et al., 2018; De Sousa Jabbour et al., 2018; Raj et al., 2020).

The four main studied concepts in implementing I4.0 solutions are identified as: the Internet of Things (IoT), Internet of Services (IoS), Cyber-Physical Systems (CPS), and Smart Factory (SF) (Li et al., 2014; Hermann et al., 2016).

The IoT is identified as the key enabler that allows ‘Objects’ or ‘Things’ (Ashton, 2009; Aztori et al., 2010), such as Radio Frequency Identification (RFID) tags, sensors, actuators, interacts with each other through unique addressing schemas (Dev et al., 2020). According to Rebelo et al., (2022), IoT creates a new dimension in the world of information and communication technology, where we are connected to anything, at anytime, from anywhere. In the same context, the IoS allows the distribution of value chain service and activities across the whole value-added network via internet.

The CPS allows the integration of physical and the virtual world, in which the physical processes are controlled by embedded computers and networks through a feedback loop affecting computations and vice versa (Aripin et al., 2019). For example, in the third generation CPS the sensors monitor the quantity of parts within a bin for the inventory management. As soon as the quantity falls below its reorder point, the order is automatically placed via RFID in a cloud-based manufacturing environment (Singh et al., 2015). This allows inventory management in real-time.

The Smart Factory accomplish its tasks by automatically processing the information gathered from the physical and virtual world. For instance, the information of the inventory material in the stock (physical world) can be compared with the information of simulation models (virtual world). The SF provides project managers and users the advantage of comparing the output to varying input data to assess the predictive analytics in a big data environment (Dev et al., 2020).

2.3 Blockchain technologies

Recently, the application of Blockchain technology in supply-chain logistics has become the focus of researchers (Yang et al., 2019; Elghaish et al., 2021; Pourmehdi et al., 2022). Blockchain is identified as a distributed ledger technology distinguished by decentralised operations across a consensus mechanism network (such as peer to peer), in which all data is authenticated in a chain and stored as blocks that are unchangeable once merged (Elghaish et al., 2021).

The literature identified several applications for Blockchain in the construction industry as (1) securing interim payment and automating monetary transactions, (2) reducing fragmentation in supply-chain, (3) tracking resources and efficient logistics management, (4) enhancing the quality information management based on Hyperledger fabric as decentralised systems (Hamledari and Fischer, 2021; Zhao et al., 2023).

A review of literature shows that Blockchain has not been widely used in the construction industry. However, some studies focused on developing new business models such as Bimchain which is based on integrating BIM into Blockchain in the form of a plug-in for BIM platforms (BimChain, 2018) or Blockchain of Things (BCoT) which integrating IoT and Blockchain.

Another area of focus in the application of Blockchain in the construction industry, is related to the smart contracts. Studies identified several advantages of applying smart contracts in construction projects such as automatically delivering the agreed contracts within involved parties, automatically managing project payments among stakeholders, enhancing copyright for project documentation, and acting as an acclaim submission platform. In fact, smart contracts provide automation of construction processes that traditionally rely on silos of information and multi-interactions between project stakeholders for making decisions (Elghaish et al., 2021). Wang et al. (2020) proposed a Blockchain-based supply-chain tracking system to enhance the collaboration and integration in precast construction. Das et al. (2020) used Blockchain as a decentralised environment to apply smart contracts and secure interim payment in construction projects. According to Yang et al. (2019), the interplay between block chains and smart contracts can establish a reliable relationship between stakeholders in the steel transportation industry, decrease the time of cargo staying in the port, enhance the efficiency of document processing during the waiting period, reduce operational financial risks, and make the trade between partners low-cost and more efficient. Literature shows that the application of smart contract and block chain technology can improve transportation efficiency and make transportation process more transparent.

Studies show that Blockchain has the potential to significantly improve IoT-related systems through creating a distributed system (Elghaish et al., 2021; Pourmehdi et al., 2022). BCoT as a new concept is introduced to exploit the combined advantages of IoT and Blockchain. Researchers effectively attempted to integrate IoT and Blockchain to provide practical solutions such as tracking resources in construction sites, reducing fragmentation of data in supply-chains, and fostering digital transformation in the construction industry.

Although many researchers conducted studies on these topics, yet the literature shows a gap in the influence of I4.0 technologies on improving supply-chain management practices (Manavalan and Jayakrishna, 2019). The applications of these technologies in real case studies in practice are still very low. Considering the influence of both I4.0 and RLs approaches on improving the economic, environmental, and social statuses of construction projects (Tran-Dang et al., 2020; Sun et al., 2022; Zhao et al., 2023), more research is required to study their mutual impacts on sustainability in theory and practice. In this article, a case study in a steel manufacturing plant is conducted to propose an IoT-Blockchain based model to address the existing challenges in steel supply-chain management processes. The selected manufacturer losses significant amount of time and money annually, due to applying traditional supply-chain management processes and plans to implement I4.0 initiatives on their logistic and RLs processes to have a sustainable and efficient delivery structure. The proposed IoT structure aims to support this transition by proposing a digital solution for enhancing the company's current steel supply-chain management techniques.

3 RESEARCH METHODOLOGY

The research methodology, as shown in Figure 1, consists of the following activities: identification of digitalisation objectives, collecting data, and designing the IoT-based solution model. The first step is to identify the logistic management problems that exist in construction projects by reviewing the literature and supplementing it with focus group discussions with project participants and industry experts. Then, in the next step, various phases of a case study project are monitored, and observed processes data are collected, which will be used to develop an intelligent logistic management model in the next step. In the third step, the study presents an IoT-Blockchain based architecture that seeks to address the identified problems. Finally, the impacts of the proposed architecture, in contrast with the traditional logistic management methods, on sustainability measures is discussed.

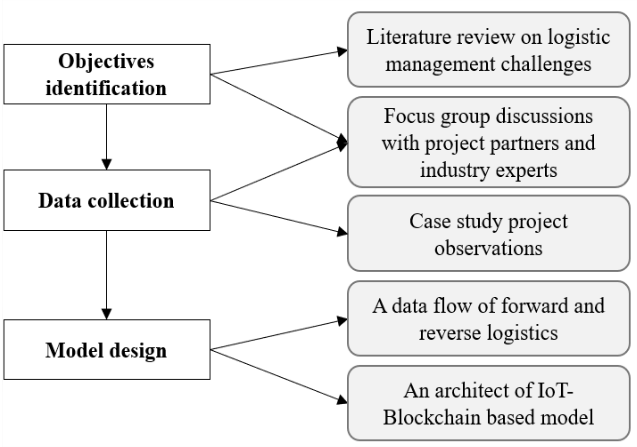

Figure 1. Research methodology

4 IDENTIFICATION OF DIGITALISATION OBJECTIVES

To identify the digitalization objectives, we have selected a supply-chain of a steel bar which is produced from raw material in a steel manufacturing company located in Quebec, Canada. Every year, the studied company produces many of these steel bars, as temporary that are used to frame prefabricated steel elements on site. These bars will be disassembled and returned to the plant, after the main structure is completely installed. During the process of sending, installing, and returning these steel bars, many of them are lost, damaged, or stolen. The makes the company to undergo significant annual costs to replace them. The inventory management process of the selected steel bars was significantly manual, time-consuming, and error prone as well. The company is continuously looking for possible approaches to improve and automate their logistics management process using industry 4.0 technologies. Based on the proposed IoT structure, the forward and reverse logistics of steel bars would be tracked automatically, which allows project participants to save time, energy, and cost through accessing real time digital information of the project supply-chain.

To understand the digital transformation objectives for enhancing the steel bar logistics processes, we have conducted virtual and physical observations, interviews, and focus group discussions with the plant director, project managers, site supervisors, and transportation employees. During the observations and interviews, we investigated the existing problems for the logistics management, collected evidence, and gathered information to categorize deficiencies and define improvement objectives. Based on the literature review results and interviews with project participants, five categories of challenges associated with logistic management in the steel industry are identified as below:

- *Lack of transparency:* project information and documents and records are not available to all project's stakeholders.
- *Lack of traceability:* steel products cannot be tracked in the whole project lifecycle.

- *Mutability of models and databases:* project databases and documents can be modified without thorough supervision.
- *Centralization of information:* logistics information is managed in a centralized manner, where they can only be controlled by one party.
- *Low privacy issue:* logistics information, such as financial information, may involve privacy and security issues.

5 DATA COLLECTION

To collect data, we selected a modular construction project and focused on delivery and logistic management of steel bars to design the IoT-Blackchain based solution. As shown in Figure 2, the project was an industrial warehouse with two buildings, including prefabricated steel products.

Figure 2. The selected project in this study

The project was awarded under a design-build delivery method, and project stakeholders used BIM and Revit models during the design, fabrication, and construction phases of the project. Figure 3, shows the BIM model that have been used for this project. First, the selected manufacturer produced modular components in the plant, and ship them to the site. Then, using the steel bars as temporary supports, the modular components were assembled into a volumetric module onsite. Once the installation was completed, the steel bars were disassembled, re-bundled in steel racks, loaded on trucks, and returned to the plant. We have performed several site and plant visits and conducted interviews and focus group discussions with site supervisors and plant managers, to visualize logistics management steps and identify process wastes such as over-production, over-processing, lost time, poor service, and information gaps (Rankohi et al., 2021).

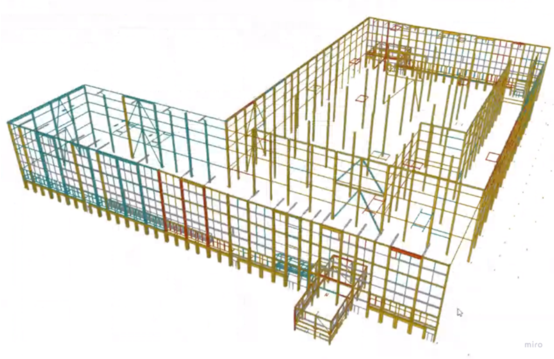

Figure 3. BIM model of the studied project

6 MODEL DESIGN

6.1 *Forward and reverse logistics data flow*

To design the model, we focused on bars' return management process and developed planning steps diagram in a push/pull similar to the study conducted by Rankohi et al. (2021). Figure 4 demonstrates the basic data flow of forward and reverse logistics activities. We explored various steps in focus group discussions and identified that more than 50% of manual steps could be eliminated or improved through using a digital reverse logistic management platform. This means there was more than 50% chance of increasing the efficiency and improving the whole process. Four main activities in reverse logistics are specified in this study, which are generally applied across various organizations that use RLs including: network design, collection, warehousing, and processing (Wilson et al., 2022).

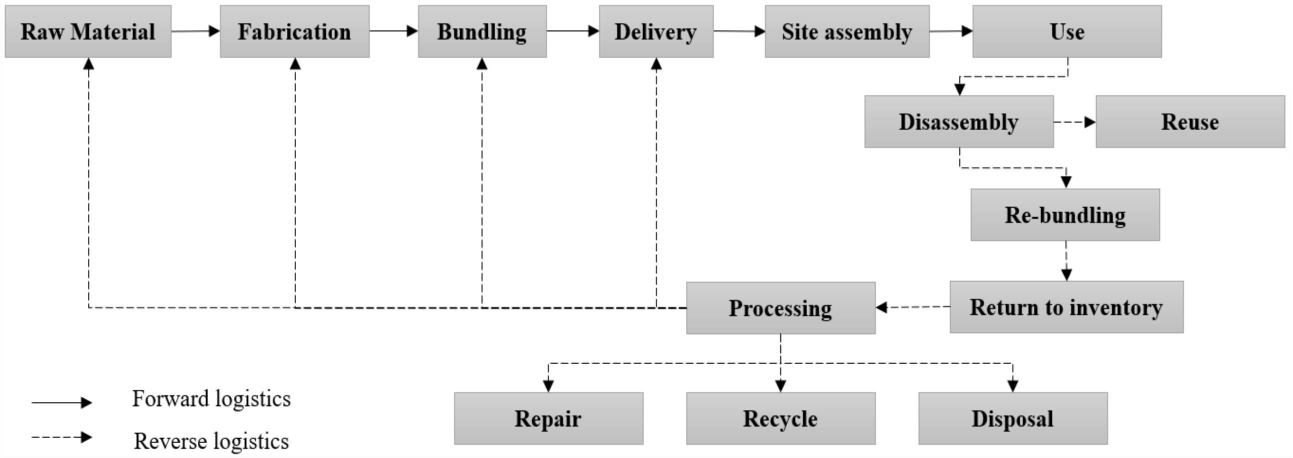

Figure 4. The basic data flow of forward and reverse logistics

6.2 *Proposed IoT-Blockchain logistics architecture*

Based on these activities, we developed the proposed IoT-Blockchain based reverse logistics management architecture, as shown in Figure 5.

The developed steel bar tracking system is based on using barcodes, RFID antennas, and readers for sensing and collecting data. The data transmission is done by WiFi; the integration layer is covered by the RFID reader's company; and finally, analysis and decisions layers are the inventory operators and company engineers' responsibilities. As shown in Figure 5, the proposed architecture consists of three main layers: *perception, network, and service layers.*

The *perception layer* consists of coding, information acquisition, and information access phases. In the coding phase, an ID number is assigned to each steel bar. Then the bars can be recognized in the whole cycle of the IoT. For instance, clients are provided with barcodes (installed on the steel bar racks or shown on 2D drawings). They scan these barcodes with their smart phones or tablets on site, which direct them to the company's web-based steel bar application. This application is equipped with mobile tag reader technologies, which are used by the clients to make sure they have collected all received steel bars in returning racks. In addition, clients can use this application to send automated alerts to project managers to inform that the steel bar racks are ready for pick-up and return to the manufacturing plant inventory. The information acquisition phase is the source of the IoT. In this phase, data is collected, and objects are identified via RFID tags. The information access phase is to transmit the obtained information from the collection phase to the network layer. The information transmission network can be mobile communication network (i.e., GSM, TD-SCDMA, WiMAX, WiFi, etc.).

The proposed *network layer* is a network platform, working based on IPV6. It consists of a large intelligent network, which is capable of utilizing all the resources in the network. Within the network layer, we have the information integration layer over the cloud, to manage and control the collected data in the network in real-time. In order to provide a good service interface to the application service layer for the clients, the data is reorganized, filtered, integrated, and transformed into the content service in the service-oriented-architecture (SOA). The blockchain in the network layer, has a data layer itself which records the steel logistics information. Its main components are data blocks, chain structure, time stamp, hash function, Merkle tree, and asymmetric encryption algorithm (Wang et al., 2019). The main function of blockchain is to provide a secured and decentralized network for smart financial management of the logistics process.

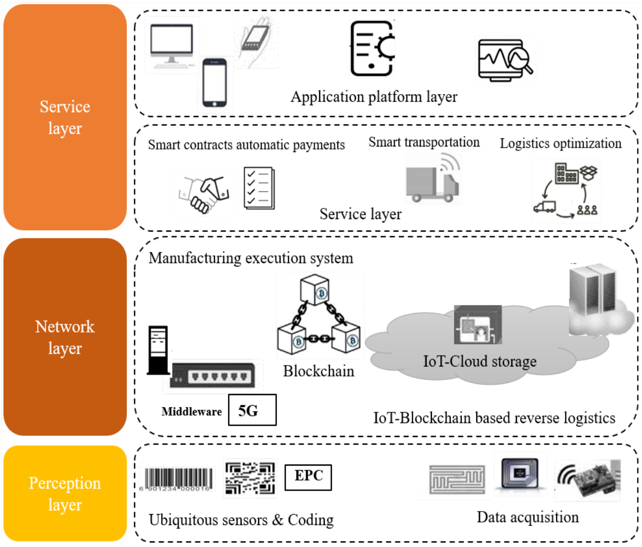

Figure 5. The proposed steel supply-chain architecture

The IoT-Blockchains based layer is designed to meet four essential characteristics of being a: decentralized, trust-less, reliable database with a collective maintenance (Wang et al., 2019). The goal is to create a trusted network in an environment of information uncertainty, where all parties can exchange information without being worried about data corrupting (Elghaish et al., 2021). In fact, as a large-scale collaboration means to manage logistics information, this layer aims to address the issues of complex transaction costs and multi-agent information sharing through supporting "decentralization" and "mutual trust" mechanisms in structural steel supply-chain (Pourmehdi et al., 2022). In this layer data from various digital providers such as project documents, BIM models, site drawings, and project schedules would be processed, based on which the operational tasks would be carried out. This layer evaluates real-time data to maintain connectivity and collaboration between the project stakeholders.

Finally, the *service or application layer* integrates the service capabilities and provides the application service to the users, such as project owners, truck drivers, project directors and coordinators, site supervisors, and inventory managers (Isikdag et al., 2012). This layer involves the application of relevant data for business and operational management tasks by diverse partners. In the user interaction interface, this layer receives, processes, and displays the data input between multiple users, such as owner (e.g., government), designers, engineers, production teams, transportation managers, and construction crews. Based on users' identity and information, the system provides different access interfaces and allocates various corresponding functions or data permissions (Li et al., 2014).

6.3 Autonomes digital process

The proposed IoT-Blockchain based steel supply-chain management process has the following steps:

Step 1: steel bars are bundled in steel racks, which pass through the shipping doors located in the inventory shop floor. Then, these racks will be loaded on delivery trucks to be shipped to the site. RFID tag reader identifies the tags, which pass through the doors. For the reading purpose, tags are placed on each of the steel bars, so they all have a unique ID, which carries information such as the type of the steel bar. When the bars are passing through the exiting gates, two RFID antennas emit Radio Frequency waves that are captured by the antennas of each of the labels and are returned to the RFID antennas with the information regarding the identification tag ID and number of each of the bars. This captured information is then transmitted from the RFID antennas to an antenna's hub. RFID readers read the information from the antenna's hub and a specific software transforms it to be exported. The exported information can be used by project participants (managers, clients, truck drivers, etc.) via online user application, transmitted by API, and integrated with the plant's inventory management system.

Step 2: site supervisors receive the racks onsite, unbundle the bars from the racks, install them as temporary supports during the installation of other steel elements, and disassemble them once the installation process is complete. Once disassembled, the site labours bundle used bars back in racks, scan racks' barcodes with their smart phones or tablets, use company's web-based application, upload pictures of loaded racks, enter preferred pick-up date, receive pictures' safety approval note, and the pick-up date confirmation from the plant's inventory managers.

Step 3: the logistic department brings back the racks to the plant. The returned racks pass through the shipping doors and the tags' reading information is recorded again by RFID readers. The information of the returned bars is collected (quantities, statuses, etc.). The collected data is automatically transferred to the cloud-based platform, comparison charts are generated, and difference between sent and received bars are calculated automatically in real-time. The calculated data will be shared between various project platforms (such as BIM 360, PlanGrid, MS project, etc.). An automatic notification, which shows the total differences (if any), is sent to the project managers, inventory managers, and the clients.

Step 4: the trucking and delivery fees would be managed at this stage. To speed-up the delivery payment, a Blockchain-based self-executed smart contract is adopted in this model, where contracting clauses are embedded originally, based on which the associated stakeholders would be paid automatically and with no delays.

Step 5: the project management team can quickly and easily make business decisions based on the received tracking information (i.e., charging clients who did not return all bars, fabricating the missing bars, etc.). For instance, the fabrication teams can start the re-manufacturing or repair processes for the missing or damaged pieces. The project managers can track the project progress on their schedule and BIM models, and the site supervisors can order the next load of materials to be delivered on site.

7 DISCUSSION

The tracking and monitoring service provided by the combined application of IoT-Blockchain tools enable integration with the enterprise systems to support secured and decentralized decision-making activities (Valente et al., 2017). The integration of product tracking in the daily operation of a steel manufacturing plant would increase automation levels by reducing manual tasks in various procedure, for instance in inventory management practices (Mourtzis et al., 2018). While IoT increases the automation, it also affects the project sustainability (Siepmann and Graef, 2016). According to Kaur and Kaur (2017), IoT provides a platform for person-to-person (P2P), machine-to-machine (M2M) and person-to-machine (P2M) communications and interactions. In this section, we aimed to understand the potential impacts of these interactions on three domains of sustainability, as shown in Figure 6, in structural steel projects as: economic, environmental, and social aspects.

Economic impacts applying the proposed model enhances the value networks which refers to the integration of IT systems, processes, and data flows between various stakeholders and companies. For example, integration between different clients, suppliers, and external partners enables stronger collaboration with value chain partners across enterprise borders (Underwood and Isikdag, 2011). In this case study, the proposed IoT solution can help various partners from different disciplines (external customer, internal teams, engineers, and sale department) work together simultaneously and more efficiently. The P2P (i.e., the client to the plant management team, the logistic team to the client, etc.), and P2M (i.e., reader alerts for the missing steel bars to the inventory management team) communication and collaboration over the cloud platform, made the whole process shorter and less error-prone than the traditional method. This results in a reduction of operating and logistics costs. Less transportation costs, better product conditions, less fuel consumptions, advanced business models, higher production rates, and lower associated risks are some of the economic sustainability results of applying the proposed architecture for logistics and reverse logistics management of steel products.

Environmental impacts applying the proposed model to perform reverse logistics management process across the entire value chain can result in a reduction of internal operating costs, energy consumptions, and delays in steel fabrication manufacturing. This ultimately can reduce green house gas emissions through reducing fabrication times in steel fabrication plants. In this model, cyber-physical systems enhance digital integration of the value chain, thus reducing wastes. In the conducted case study, the M2M (i.e., automatically printed customized digital BOL) communication improved digital integration through reducing manual paper work, which was being performed by the inventory management team. In addition, the real-time data collection and analytical abilities provided by the presented IoT-Blockchain based architecture improves the level of resource sharing among various project partners in a reverse logistics management system. This could offset the augmented cost and environmental impacts of complex projects between geographically dispersed customers.

Social impacts the digital collaborations through IoT platform provided team members with a real-time access to the project information and ultimately reduced the amount of human errors. This ultimately reduces the working hours and can influence working efficiencies. Smart human-machine collaboration and cooperation create added value to the end product, either during repair, recycling or disposal processes. This can reduce wastes and increase productivity. According to Rankohi et al. (2021) P2P and P2M collaborations improve horizontal and vertical integrations. These levels of integration improve communication and collaboration between project participants and ultimately affect team esprits.

In summary, the proposed architecture links reverse logistics activities, IoT-Blockchain enabled cyber-physical connection and interaction, and technological enablers for the smart transformation of data collecting, sorting, processing, managing, remanufacturing and recycling, transportation, and waste disposal. In this regard, the proposed model can provide more data accessibility, security, connectivity, intelligence, flexible automation, and better resource sharing, through which the sustainable goals can be well-archived by improvement of various reverse logistics activities and processes.

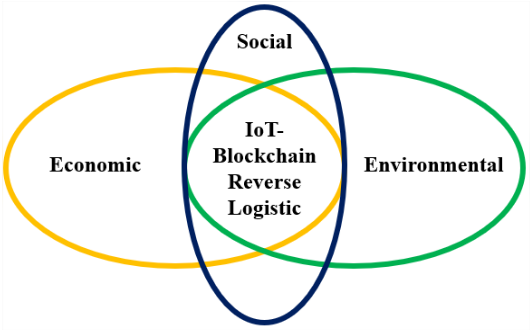

Figure 6. The sustainability aspects of the proposed architecture

8 CONCLUSION

Traditional logistic management is challenged by inadequate integration, laborious data accessibility, and unsatisfactory information security. The current adoption of smart applications for transportation and logistics management has brought opportunities for upgraded information digitization and data integrity.

Therefore, this paper proposes a IoT-Blockchain based framework for logistic and reverse logistics management in steel construction projects. The proposed model incorporates an IoT-based application to match steel supply/demand logistics and a blockchain technology application in a smart contract layer for handling projects' financial related issues.

The proposed architecture is based on efficient adoption of I4.0 initiatives combined with sustainable steel RLs systems. The real-time information sharing provided by the proposed model can help firms to take just-in-time corrective measures to guarantee product quality. Also, IoT-Blockchain applications can increase automation and productivity in steel manufacturing plants and reduce inventory losses, which result in enhancing customer-service levels.

The study limitation is in evaluating the proposed model of using IoT-Blockchain based technologies to observe the impact of the changes caused by this architecture on the sustainability of the steel RLs system. A potential future study can be evaluating the conditions of the steel logistics management in several case studies before and after adopting this model for a better evaluation of its effects on the processes of the logistics system and sustainability. Future research is thus encouraged to evaluate the proposed architecture.

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