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USING LOW-CODE AND ARTIFICIAL INTELLIGENCE TO SUPPORT CONTINUOUS IMPROVEMENT IN THE CONSTRUCTION INDUSTRY

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ABSTRACT

Low-code is a new technology paradigm used to support digitalization in different industries. Nevertheless, there are no studies analyzing the implications of this technology in the construction industry context. Through action research, this paper explores the potential of low-code to support continuous improvement of construction processes. The authors present the development and implementation of a low-code/artificial intelligence (AI)-based solution to automate data processing from paper delivery notes on-site. The as-is process was measured and compared against the low-code/AI powered process to verify efficiency gains. The development process of the digital solution was also analyzed to derive the findings of the study. The implementation of the digital solution resulted in 78% process time savings. The study also reveals the importance of involving people closer to operations in the development process, which resulted in efficient elicitation of requirements and the delivery of a solution meeting the needs of the end users. This paper highlights the potential of low-code productive development practices to support the digitalization in the construction industry. It also enlightens areas for further research and encourages the development of additional case studies to provide evidence of the benefits and limitations of using low-code to support continuous improvement in the construction industry.

KEYWORDS

Low-code, no-code, artificial intelligence, lean construction, continuous improvement

INTRODUCTION

Digitalization and the adoption of construction 4.0 offers the Architecture Engineering and Construction (AEC) industry a great opportunity to improve processes and productivity (Chui & Mischke, 2019). However, the architecture, engineering, and construction (AEC) sector lags behind other industries in terms of digitalization. According to the MGI Industry Digitization Index from 2015, construction was ranked third-to-last, ahead only of agriculture and hunting (Agarwal et al., 2016).

This slow pace of digitalization is usually attributable to systematic industry barriers such as fragmentation, organizational decentralization, and the uniqueness and transience nature of construction projects (Dubois & Gadde, 2002; Hall et al., 2020). In addition to these barriers, it is widely agreed that the main obstacles to digitalization in construction are not mainly

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technology-related challenges, but rather insufficient understanding of construction operations (Fenves 1996; Koskela & Kazi, 2003) and the socio-technical environment, which encompasses cultural and human factors relevant to digitalization (Lundberg et al., 2022; Xue et al., 2012) . This lack of understanding translates into a critical disconnection between the requirements of the industry and the way in which technologies are developed and implemented (Arayici et al., 2006).

Xue et al. (2012) acknowledge that despite the efforts put on the development of information technology to improve project performance, practitioners still face several difficulties when bringing it into real-life management and operational processes. It is therefore reasonable to assume that bringing the process of technology development closer to construction operations is particularly relevant to support digitalization and productivity improvement in the construction industry. Bridging technology and operations increases end-user participation in the development process, facilitates the elicitation of requirements and the validation of potential solutions, which in turn helps to ensure that the final solution meets end-user requirements.

An emerging technology paradigm offering opportunities in this area is low-code development (Richardson & Rymer, 2014). Low-code development allows individuals with limited coding skills to develop and implement digital solutions targeted to specific business needs. The potential of low-code lies in its capacity to allow people closer to operations (practitioners or end-users) to find digital solutions to their business challenges. Some authors refer to these individuals as “citizen developers” (Everhard, 2019; Olariu et al. 2016).

Bringing the technology development process closer to operations also aligns with Lean Principles. According to Liker & Meier (2013), from a lean perspective technology has to fit people and the processes they use in order to maximize its value. Furthermore, prior to digitalizing construction processes, it is necessary to assure their stability. Otherwise, digitalization could exacerbate existing problems and introduce new barriers. Stable processes complemented with suitable technology provide an opportunity for developing agile and more efficient information flows (McHugh et al. 2022).

Market and scientific literature forecast that low-code and citizen developers will play a fundamental role in enabling the digitalization of different industries (Prinz et al., 2021). Low-code has been already explored to improve processes in different business scenarios, such as manufacturing and supply chain management. Nevertheless, to the best of the authors knowledge there is no research contextualizing the use of low-code to support digitalization in the construction industry. This paper aims to fill this gap by providing insights about the use of low-code and AI to address challenges in construction processes.

RELATED LITERATURE

LOW-CODE

Low-code is a relatively new development paradigm. The term low-code was introduced by Richardson & Rymer (2014) who argue that it emerged in response to rapidly changing business environments and demands for faster and cheaper software development. Low-code development platforms support fast development of customer-facing applications, requiring minimal hand-coding and enabling productive development practices.

In practical terms, low-code lowers the barriers between software/application requirements and delivery, speeding up the development process and enabling higher customer participation in projects (Richardson & Rymer, 2014). Low-code platform users (citizen developers) use an application modeler with an intuitive graphical interface offering different predefined constructs assisting in the application development process. The user drags and drops different pre-defined constructs in the graphical interface which automatically generate the code in the background based on the choices made by the user. In this way, a user without advanced coding/programming skills can design and deliver fully functional applications or digital solutions without necessarily requiring the support of professional software developers (Sahay et al., 2020).

Some authors, however, argue that more than a disrupting technology, low-code can be considered as the evolution of model-driven engineering and Computer-Aided Software Engineering (CASE) concepts. Some authors even claim that the rise in low-code popularity can be attributable mainly to a rebranding and marketing of its predecessor concepts (Bock & Frank, 2021; Cabot 2020).

Aside from the debate about its roots, low-code ability to enable fast delivery of digital solutions is generating a significant momentum. Forecasts suggest that by 2024, 65% of business applications will be created using some form of low-code technology (Vincent et al., 2019), and the number of citizen developers will eventually surpass that of professional developers (Wong et al., 2019). If these predictions materialize, low-code technology will significantly influence digitalization in different industries and the way in which business processes are designed and run. In fact, the Project Management Institute (PMI) has launched an educational program to prepare the next generation of citizen developers (PMI, 2021). Scientific interest on low-code is also rising (Prinz et al., 2021), with some research projects focusing entirely on preparing future engineers make low-code scalable (e.g., Tisi et al., 2019).

Low-code has already been explored in different industries. Waszkowski (2019), used a low-code platform for automating business processes. The author emphasized that one of the primary advantages of low-code lies in its ability to significantly reduce the time required to transfer requirements from end users to information technology developers. Wolff (2019), described various examples of low-code implementation for digitalizing workflows services and inventory management. The author argued that low-code is especially suitable for manufacturing, given that most engineers who oversee business processes are acquainted with a programming language making the low-code environment relatively familiar to them. Sanchis et al. (2020) assessed the feasibility of using low-code to facilitate digitalization in the manufacturing sector. The authors emphasized that low-code interfaces with Internet of Things (IoT) and Industry 4.0 can greatly simplify the transfer of information and optimize equipment and products across the entire value chain. Wang et al. (2022) used low-code to develop a small-scale Enterprise Resource Planning (ERP) system tailored to the requirements of the context of hydrogen equipment manufacturing. The authors reported the advantages of the low-code-based ERP system compared to the prior semi-manual Microsoft Excel method. They also emphasized the potential of low-code to facilitate innovation and enhance business agility within an organization.

The authors could not identify any documented implementation low-code in the context of construction industry. That is one of the primary contributions to literature of this study.

Use Of AI In Construction To Extract Information From Documents

Low-code technology is evolving rapidly, and vendors are competing to offer the most intuitive and faster development environment (Vincent et al., 2019). Some vendors are even integrating AI modules into their platforms allowing users to create models to automate tasks such as paper form processing and object detection.

AI-enabled document processing can help reduce the time it takes to manually extract data from documents, while also reducing errors. AI-based document processing is used to scan and interpret documents, extracting the key data points that are needed for further analysis. (Cisterna, Seibel, et al., 2022)

Optical Character Recognition (OCR) and Natural Language Processing (NLP) are two AI technologies that could have a substantial impact in the construction sector (Locatelli et al., 2021; Wolber et al. 2021). OCR technology enables the conversion of scanned or digital images into text that is machine-readable, enabling the automation of human data entry and the digitalization of paper-based operations (Hamad & Kaya, 2016). NLP enables computers to comprehend and analyse human language, enabling them to interpret and process information from unstructured text data. (Indurkhya & Damerau, 2010)

One example of the use of OCR in the construction industry is in the digitalization of contracts and invoices. By utilizing OCR, companies can automatically extract information from these documents and incorporate it into their digital systems, thereby decreasing the need for manual data entry and enhancing accuracy and productivity. This also enables for improved tracking and management of crucial data, such as payment schedules and project deadlines.

NLP can be utilized in numerous ways to enhance construction operations. For example, it can be used to evaluate construction project reports and extract vital information such as status updates, budgets, and resource use. This data can then be used to track project performance and detect possible issues early on, enabling speedier resolution and improved project outcomes. NLP can also be used to automate communication amongst team members, such as informing project managers of potential delays or providing deadline reminders.

Another scenario is the application of NLP to the evaluation of construction site safety reports. By examining these records, construction organizations can find trends and patterns associated with safety events and utilize this data to improve safety processes and reduce the likelihood of accidents.

In conclusion, the employment of OCR and NLP in the construction sector represents a huge opportunity to enhance process efficiency and productivity. These technologies have the potential to make construction projects more streamlined, cost-effective, and secure by automating human operations and extracting important information from data.

RESEARCH METHODOLOGY

The authors used action research. Action research supports addressing practical problem-solving while expanding scientific knowledge based on collaboration of different actors within a mutually accepted ethical framework. The characteristics of action research offer an adequate framework for conducting applied research in the construction industry and foster collaboration between academia and industry practitioners (Azhar et al., 2010).

The authors collaborated with a construction project team in the implementation of a low-code/AI digital solution to address inefficiencies in the process of collecting and processing data contained in paper forms. The authors supported the team in the development process of the digital solution. The as-is process was mapped, timed, and ultimately contrasted with the improved low-code/AI-enabled process to identify the efficiencies that could be achieved through the implementation of the technology. Insights from the site project manager were captured through semi-structured interviews to support the findings of the study.

PROJECT BACKGROUND

The project involves the construction of a large tunnel in Switzerland. The operational challenges are related to a typical situation of manual data processing on construction sites. This process is depicted in Figure 1. For each concrete delivery truck, the construction team receives the corresponding delivery note onsite. Relevant information in the document (e.g., receipt number, type of material, date, quantity, etc.) is manually transferred to a spreadsheet to keep track of materials delivered on-site. The information is then processed to create a dashboard to visualize the information.

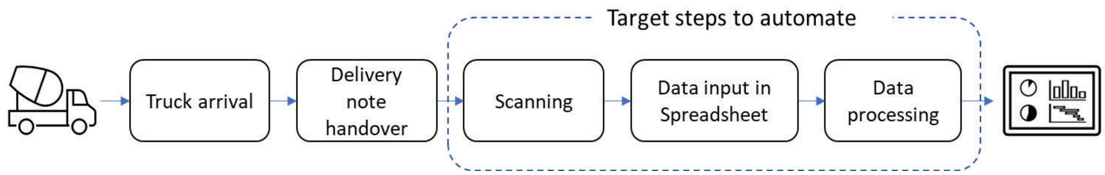

Figure 1: "As-is" Process to Collect and Process Data from Delivery Notes.

This process has several drawbacks. First, the manual transfer of information from the receipt to the spreadsheet is time consuming and prone to errors. People devote daily time to perform this task instead of focusing to deliver value to the project. Second, in many cases the responsible person does not perform the task on a regular basis. This generates a backlog of delivery notes which are not processed baring the project team to have accurate and timely information about the quantity of material received onsite. Although not considered in the scope of the process improvement, the delay in information processing also impacts downstream work. Since there is not an overview of the material received, the finance team is unable to centrally process invoices delaying the payment suppliers. The team aimed to address some of the inefficiencies in the process by leveraging the use of the low-code Microsoft Power Platform. Microsoft Power Platform includes a group of cloud-based applications supporting the automation of business processes and the creation of applications using low-code (Microsoft, 2022). The platform has also available an AI module which support training models to extract information from documents and images.

Architecture of the System and Updated Process

The architecture of the system is depicted in Figure 2. The digital solution leverages the use of the Microsoft AI builder, Power Automate, SharePoint, Excel, and Power BI. In the updated process, the user scans the delivery note and save it in a designated folder in Microsoft SharePoint. This action triggers a digital workflow in Power Automate which recalls an AI model created in Microsoft AI builder. This model is trained to read and extract relevant information from delivery notes. Power Automate then creates a new row with this data in a Microsoft Excel table. In parallel, the workflow triggers an automated confirmation email to the user including relevant information extracted from the document, including the scanned file as attachment for internal archive. Via an automated query, Power BI imports the table, organized the data, and display it based on visuals defined by the team.

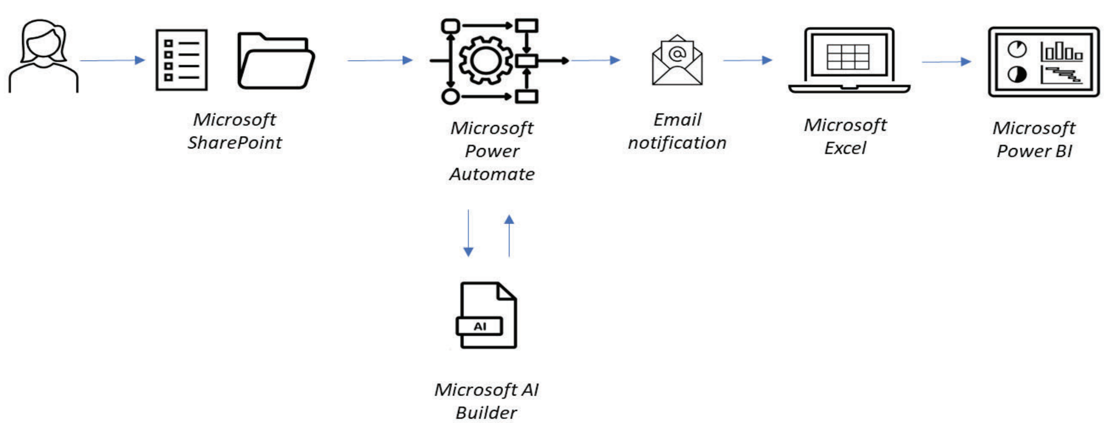

Figure 2: System Architecture.

The first step to develop the solution required training of an AI model able to extract relevant information from scanned delivery notes in .pdf format. For this purpose, the model was trained using 10 standard samples from a specific supplier. This step requires the user indicating manually the areas of the delivery notes where relevant data is located. In our case, we piloted the model using the name of the supplier, receipt number, date of delivery, the type of material delivered and corresponding quantity. After the first rounds with the sample delivery notes, the model provided an indication of the confidence for the different field (Figure 3). The model can be further trained to increase confidence requiring more samples to improve the AI model.

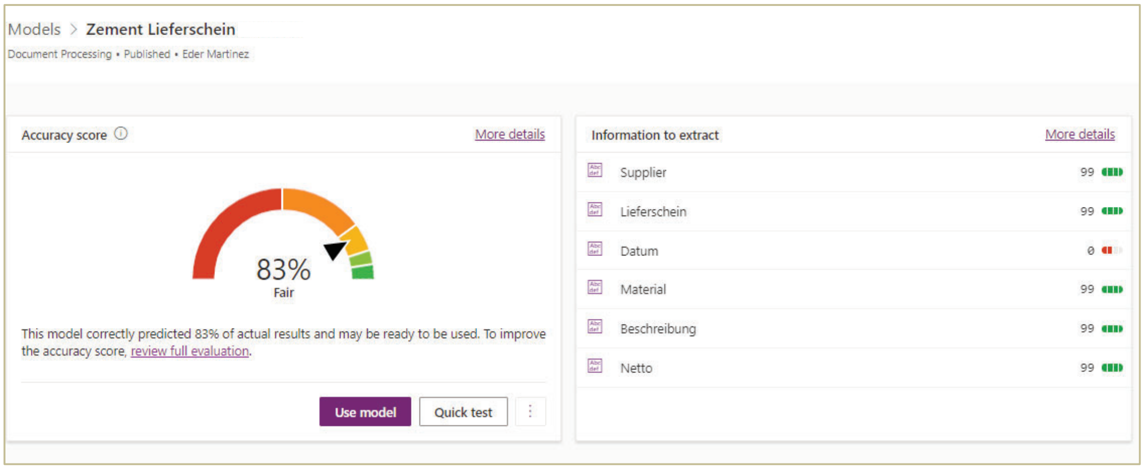

Figure 3: AI Model Accuracy Score.

DIGITALIZED VERSUS TRADITIONAL PROCESS

The new low-code/AI workflow removes several inefficiencies from the original process since the user no longer has to manually type the information in the spreadsheet. On average, the whole process took the user 7 minutes per delivery note. In contrast, the automated workflow takes on average 1.5 minutes, meaning that 5.5 minutes are saved each time the process runs, equivalent to 78% of the original process time.

The digital workflow in Power Automate itself takes in average 25 seconds, varying depending on the quality of the connection onsite and the amount of data in the paper form. For this calculation, we run the workflow 10 times and computed the average. An example of Power Automate workflow timing is depicted in Figure 4.

Furthermore, the digital process discourages producing a backlog of unprocessed delivery notes. Capturing of data, as well as the transformation process required to make information available is triggered as soon as the scanned file is stored in the designated folder. The solution also supports processes downstream since the information is directly made available to the finance department to process related payments.

The time savings may appear marginal when analysing a single process run. Nevertheless, efficiency gains can be scaled up and computed considering the magnitude of the project. It is expected that this project will receive more than 2,000 delivery notes only for this type of material and supplier. This translates into 183 working hours saved for the project. This does not consider other type of delivery notes (materials, equipment, etc.) or potential re-use of the low-code/AI solution in other projects within the organization.

The development process to put this solution together took approximately 1.5 working hours. That includes training the AI model (considering 10 delivery notes) and designing the workflow in Power Automate. This considers a user already familiarized with the Microsoft Power Platform. For different type of delivery notes (e.g., different layout or supplier), the AI model should be re-trained, but the digital workflow logic could be reused.

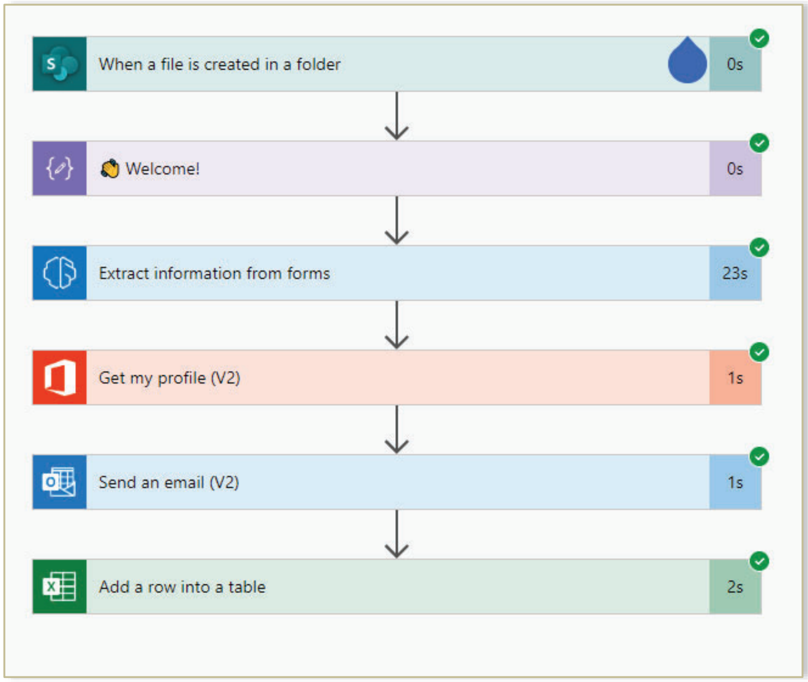

Figure 4: Power Automate Workflow and Duration.

DISCUSSION

THE POTENTIAL OF LOW-CODE IN THE CONSTRUCTION INDUSTRY

This experience demonstrates the potential of low-code and AI to support the digitalization of specific processes in the construction sites. The unique nature of construction results in a variety of specialized processes and procedures, making it challenging to find a ready-made digital solution in the market for those particular cases. Developing a digital solution in the traditional way would arguably require the involvement of information technology experts to support in the development process, which may result costly and time consuming.

With the availability of low-code and AI solutions, people closer to construction operations (acting as citizen developers) can experiment to develop their own applications and digital solutions. Individuals with a closer proximity to operations have a better understanding of end-user pain points, enabling them to efficiently translate requirements into features of the application, resulting in a more streamlined development process. Resulting from this experience, the organization involved in this experience is seeking to find further use cases where the use of low-code can result in increased productivity gains. The authors plan to report on these cases to build up more evidence and knowledge about the use of low-code in the construction industry.

It is reasonable to expect that, like other industries, the use of low-code platforms in the construction industry will grow and become more widespread. This resulting from several factors, including the increasing demand for digital solutions, the need for faster and more efficient construction processes, and the growing recognition of the benefits of low-code platforms. It is also expected that the capabilities of low-code platforms will continue to expand and evolve, enabling the creation of increasingly advanced and complex solutions. This may include the integration of cutting-edge technologies such as artificial intelligence and machine learning, further enhancing the transformative potential of low-code platforms in the construction industry.

In terms of the citizen developer, it is worth to note that the use of low-code also requires certain level of computing knowledge, including data modelling in order to proper delivery an application. Some authors even use the term “low-code” and “no-code" interchangeably (e.g., Hurlburt (2021)) which may be misleading considering the need of minimum computing knowledge to develop applications.

LOW-CODE TECHNOLOGY AND LEAN CONSTRUCTION

Lean construction philosophy seeks to minimize waste of materials, time, and effort to maximize the value delivered to customers (Koskela et al., 2002). In this regard, the use of the low-code/AI solution effectively supported the project team to remove unnecessary work from the process. Along with waste reduction, low-code also supports the team having relevant data available to learn and steer the project. It is known that that construction sites are very rich in terms of data, but most of this data remain analogue and it is barely used for the benefit of the project. By facilitating the data capturing and transformation process, low-code could be an enabler to support projects to better leverage the use of data, facilitating access to relevant Key Performance Indicators supporting the Plan-Do-Check-Act (PDCA) continuous improvement cycle. Our experience indicates that digital solutions or applications developed with low-code platforms do not generate new file types, but rather exploits existing file formats to facilitate interoperability across software. This helps integrate the fragmented software landscape and data silos rather than fragment them further.

Arguably, the type of technology behind the low-code/AI-powered solution described in this study is not ground-breaking. However, the value of the approach lies in the productive development practices that it enables. That is, lowering the technical barriers that allow individuals without advanced coding expertise to create digital workflows to streamline processes and harness the data available on construction sites. This approach provides an ideal environment for project teams to use technology to integrate the project delivery approach (Martinez et al., 2022), supporting both people and processes, in line with the principles of lean construction. (Liker & Meier, 2013).

As per the results of this experience, it is expected that the combination of lean construction and low-code platforms would have a substantial impact on the future of construction projects. The streamlined processes made possible by low-code and the reduction of waste made possible by lean construction are likely to result in quicker project completion times and increased customer satisfaction. This is because of the low-code platform's capacity to simplify data capture and transformation, hence enabling better data-driven decision making. In addition, the low technical barriers of low-code solutions will enable a larger number of individuals to engage in the implementation of technology, thereby contributing to the alignment of technology with lean processes.

Low-code platforms and lean construction are likely to become even more integrated as the construction industry continues to evolve. It is anticipated that the use of AI and other sophisticated technologies in low-code platforms would expand, hence enhancing project efficiency and decreasing waste (Cisterna, Lauble, et al., 2022). Additionally, the use of low-code solutions in construction will continue to expand beyond simple workflows to include complex, data-intensive applications. This includes, for instance, the integration of relational databases such as Microsoft Dataverse, allowing the design of more complex and intensive data models.

INTERFACES TO CONTEMPORARY CONSTRUCTION INDUSTRY TOPICS

While developing and implementing the solution described in this study, the authors also realized interfaces to other contemporary construction industry topics such as Industry 4.0, Building Information Modelling (BIM), and Digital Twin. The data which can be digitalized and processed using low-code/AI could be further exploited and integrated in a larger system. For example, data captured onsite could be linked to the BIM Industry Foundation Classes (IFC) schema to enrich data available in the model. These types of interfaces offer an interesting area for further research considering the novelty of low-code in the construction industry.

LIMITATIONS

The digital solution described in this study was developed using one of the many low-code development platforms currently available in the market. This platform was already embedded in the organizational information technology landscape. As a result, the low-code platform was ready to use, and there was no need to benchmark low-code solutions and spend additional time integrating it into the organization's systems. Although low-code platforms offer similar features, the outcomes of this study could have been influenced by the platform used. In this regard, comparing the suitability of the features of low-code platforms in the context of the construction industry is also an interesting field of study. This paper also describes a single use case. The authors encourage further exploring use cases and research to build up evidence about the benefits and limitations of low-code use in the context of the construction industry.

The solution could have also considered digitalizing delivery notes at the source. That means, requesting the supplier to manage delivery notes digitally, instead of printed. Arguably, this solution requires developing and onboarding suppliers on a shared digital platform. This is an idea to explore in the future. Nevertheless, the capabilities of the low-code platform to handle the requirements of this type of solution were not assessed in this study.

CONCLUSIONS

This paper explored the use of low-code and AI to improve processes in the construction industry context. Low-code enables people with no advanced coding skills to develop and deliver digital solutions to address specific business and operational challenges. This article delves into the potential of low-code technology in facilitating the digitalization of construction-specific processes and promoting lean construction practices in this field.

This study documented the development and implementation of a low-code and AI-powered solution to extract and process data from paper delivery notes, resulting in a 78% process time savings, and the availability of processed digital data related to the process. This experience highlights the importance of the low-code approach, particularly the involvement of individuals with a closer proximity to operations in the development process. This involvement enables the effective elicitation of requirements and their translation into features of the digital solution, ensuring that the result aligns with the process and meets the end-user's needs.

The use of low-code is gaining a tremendous momentum and scientific interest. Since it is a relatively new topic, there is significant room for further research. The authors encourage the development and documentation of additional case studies to build up evidence about the benefits and limitation of using low-code to support continuous improvement in the construction industry context. Additionally, there are several low-code platforms available with different features and capabilities. Further research could involve exploring the relevant requirements of a low-code platform that align with the specifics of the construction industry.

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