DEVELOPMENT OF A PROCESS MODEL-BASED TOOL FOR CIRCULAR CONSTRUCTION SUPPLY CHAIN INTEGRATION

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Abstract

The recent research focus on circular construction supply chains challenges the integration of supply chain processes. There is a need to build simulation tools for construction, facility management, deconstruction and reuse of building components. This paper introduces a model-based tool to enhance supply chain process integration developed with Business Process Mapping and Notation (BPMN). The model captures the remanufacturing supply chain for façade products that are demounted and reapplied in a different construction project. The paper highlights the tool's potential for predictive analysis and decision support based on supply chain performances. The demonstration shows an innovative approach to CE-driven supply chains.

Introduction

The construction industry is gradually adopting the concept of circular economy (CE) as one of the major transitional goals to reduce greenhouse gas emissions and waste throughout the full building life cycle. Many recent studies have reached a consensus that supply chain wide innovation is a prerequisite for this transition, as well as a focused research agenda for this topic in construction (Akinade and Oyedele 2019; Migliore 2019; Nasir et al. 2017). Construction supply chain management (CSCM), a field of research and practice that has been active for several decades, was introduced because of the growing demand of efficient construction processes and lessons learned from LEAN manufacturing (Eriksson 2010; O'Brien, London, and Vrijhoef 2002). In the background of CE, more studies have revealed strong interest in developing more circular and closed-loop construction supply chains (Adi Wijaya and Armyn Machfudiyanto 2023; Akinade and Oyedele 2019; Incorvaja et al. 2022).

Managing and coordinating construction supply chains is an ambitious task given its 'complex', 'project-based', 'fragmented' and 'contingent' nature (Koolwijk et al. 2018; Koskela, Vrijhoef, and Dana Broft 2020; Vrijhoef and Koskela 2000). Hence, supply chain modelling could provide support for the simulation evaluation, monitoring and prediction of processes (Cheng et al. 2010; O'Brien, London, and Vrijhoef 2004). Considering that CSCM is a vast subject that has been explored by multiple disciplines from various perspectives, it is difficult to find a single model that serves all needs. Both highly abstract mathematical models and more realistic simulation models have been extensively used for the purpose of analysis and optimization in CSCM (Chen and Hammad 2023). As the new digital systems such as digital twins are further developed, more integrated models and applied tools have been proposed to depict the complex supply chain networks and business processes (Cheng et al. 2010; Neuhäuser et al. 2023). Besides, there is also a clear trend of developing CSCM models for sustainability and CE related objectives. Recently, scholars have particularly highlighted the lack of models that integrate the R strategies such as reuse, recycling and remanufacturing (Chen, Feng, and Garcia de Soto 2022; Chen and Hammad 2023; Hussein et al. 2021). Despite that many studies have already addressed various types supply chain models for different challenges of CSCM, they are in most cases based on linear economy scenarios, characterized by forward flows of products and materials. What is missing, is the modelling of circular construction supply chain operations, that, according to the literature review by Ding, Wang, and Chan (2023), shall involve reverse logistics (RL) and process integration of both forward and reverse flows.

To expand knowledge and practices in modelling circular CSCM operations, this study proposes a process centric supply chain model that represents the remanufacturing supply chain for construction products. The model partially captures and simulates the complex remanufacturing procedures in the circular supply chain of recovered construction products. In the project case, wooden frame window and door components are recovered from one demolition site and remanufactured into new façade elements for another construction site in the city of Amsterdam. The framework of Supply Chain Operations Reference Model (SCOR) is used as the core structure to model and elaborate the supply chain processes and performance indicators. And further, the business process model and notation (BPMN) language is utilized to transform the supply chain processes with more detail levels into a digital representation with the potential to build executable software with the Camunda API. A demonstration tool is designed to be accessed by different supply chain stakeholders to interact with input/ output data and gain more insights for critical decision-making.

Theoretical Base for Modelling

Modelling Supply Chain Integration for CE

The efficiency of reverse supply chains can be improved by standardizing processes and procedures, even when the buildings an components are entirely different, and even when the disciplines involved are different. This may bring more commitment and capacities from the supply chain to CE (Koolwijk et al. 2018; Teixeira and Borsato 2019). It is particularly challenging for CE oriented construction projects, given that most of these projects are still experimental pilots There is limited evidence that such practices could be repeated at greater scales. Thus supply chain integration templates for circular projects, that support repeatable processes and continuous improvement, will be highly relevant for tackling the challenges of CE in construction.

A number of studies in the field of supply chain management connected the concept of supply chain integration with the maturity of business processes (Lockamy and McCormack 2004; Trkman et al. 2007). In these frameworks, the more 'mature' supply chain processes evolve from 'Ad Hoc' business operations, where processes are not well documented or structured, to more integrated and standardized processes. The collaboration between companies improves. More repeatable and predictable procedures are set up to reduce overall costs. The model in Figure 1 by Lockamy and McCormack (2004) defines the maturity of supply chain processes in five levels based on the reference to the key supply chain processes defined in the Supply Chain Operations Reference model (SCOR). SCOR is one of the most commonly applied standards to map supply chain configurations and processes (Teixeira and Borsato 2019). The framework defines the following distinctive processes in the supply chain: plan, source, make, deliver, and return. The SCOR features a hierarchical structure of processes, which consists of four levels of detail in process descriptions. The framework provides an appropriate starting point for practitioners to define the key business processes and sub-processes in a supply chain system (Supply Chain Council (SCC) 2017).

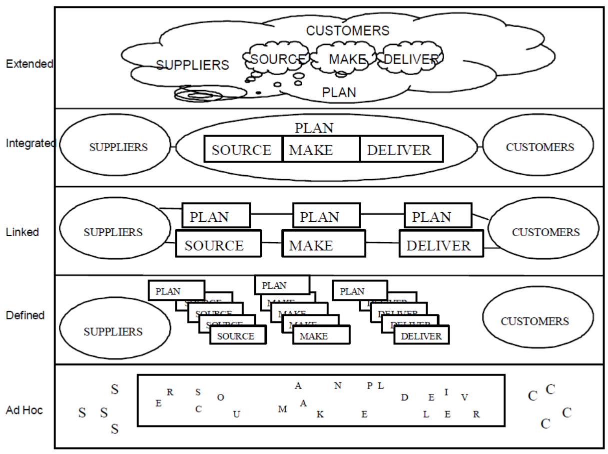

Figure 1: supply chain process maturity model, source: (Lockamy and McCormack 2004)

It would be a rather new experiment to utilize the theory of supply chain process maturity model and SCOR for CE driven initiatives, but there is clearly already a growing discussion on the potential of supply chain integration in circular and sustainable transition. Di Maria, De Marchi, and Galeazzo highlighted that the integration enabled by industry 4.0 technologies such as smart manufacturing play an mediation role for CE performance, because the enhanced links between actors in the supply chain positively affects the utilization of resources in a circular manner (2022). Similar conclusions are drawn by studies in the construction industry, addressing needs for integrating supply chain and logistics processes for the goal of CE in construction projects (Chen et al. 2022; Incorvaja et al. 2022). Modelling the processes of integrated supply chains will be a prerequisite for achieving industrialized CE.

Performance Goals for Circular CSCM

The Ellen MacArthur foundation (Ellen MacArthur Foundation 2013) makes a distinction between the technical cycle, which includes materials that have to be maintained and reprocessed as much as possible as part of a finite material stock, and the biological cycle that may be regenerated by the biosphere. In principle, circular supply chain management for the construction sector will incorporate both loops and should integrate forward and reverse flows of products and services in the full building life cycle (Ding et al. 2023; Farooque et al. 2019). In the ideal condition, a circular supply chain will require the minimum amount of primary resources for production and output zero waste, emissions or hazardous materials (Farooque et al. 2019). However, the more realistic goal definition of circular CSCM will be based on current frameworks of CE and CSCM concepts, that is to systematically integrate CE thinking and R-ladder strategies, such as recycling, remanufacturing and reusing, into the management of resources in construction supply chains, which involves all stakeholders in the construction project life cycle, including construction organizations, manufacturers and waste management agencies (Chen et al. 2022; Ding et al. 2023; Farooque et al. 2019).

The SCOR standard defines 5 main performance attributes: reliability, responsiveness, agility, costs and asset management efficiency. The standard also elaborates more performance metrics and best practices to describe and measure performance both quantitatively and qualitatively. Part of the performance aspects of SCOR already aligns with the performance goals of CE. Especially the cost and asset allocation performance is critical to circular CSCM, because currently the more desired strategies of reuse and remanufacturing of construction products are often hindered by higher material handling cost and increased logistics cost and mismatch between the moments of materials supply and demand. Therefore, in the current context of CE transition, it is reasonable to refer to the SCOR defined performance indicators and prioritize the cost performance while modelling circular construction supply chain processes, hereof the urgent practical goal is that more circular strategies may become more competitive while positioned against traditional linear supply chains.

BPMN

There are multiple ways to model business processes in a supply chain system. Languages such as BPMN and IDEF0 are upon those common standards used for business process management. BPMN is the de facto method for modelling supply chain processes due to its clear logic and visual capabilities. The language is also available in a number of commercial and open source software platforms for customizable development. The combination of SCOR and BPMN has been used by a few previous studies in the manufacturing industry for supply chain modelling (Cheng et al. 2010; Teixeira and Borsato 2019), where the potential to create dynamic and interactive models which industrial participants can understand is demonstrated.

BPMN models of the supply chain system could be approached in different configurations based on how organizational relationships are modelled. The BPMN orchestration model is the basic form that contains a single point of coordination. A collaboration model treats all processes as internal and focuses on only message flows between organizations for inter-organizational processes. The choreography model is designed to highlight interactions between organizations in contrast to internal processes (Eisner 2021). The purpose of modelling for the supply chain determines the method used in BPMN.

Model Construction

This paper proposes an explorative approach to model circular construction supply chain processes, based on demonstration cases of façade element remanufacturing. A few completed construction projects in the Netherlands already demonstrated as pilot projects to recover secondary building façade components and remanufacturer them into new building components in other projects. Based on informal interviews and workshops with the Dutch façade industry stakeholders, some key configurations of the processes are captured for this model. For the purpose of demonstrating the applicability of the model, one pilot case of façade element remanufacturing is used as an example. The case consists of two building sites, project A is a demolition site located in Amsterdam, from which wooden and glass elements from windows and doors have been demounted and then disassembled in factories to be made into new doors and windows for construction project B, which is at another location in the city. Because the part of the project related data is internal for the companies, some assumptions based on the interview and workshops and generated numerical data is used to deliver the proof of concept for the modelling and simulation process as shown in Figure 2.

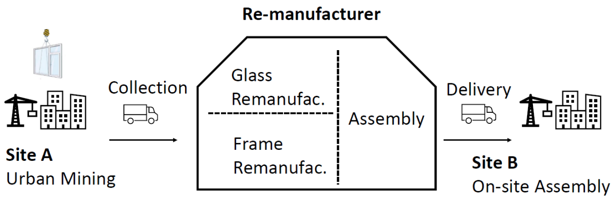

Figure 2: Illustration of the re-manufacturing supply chain

The hierarchical process model defined by SCOR 12.0 is used as the guiding standard for the modelling procedures as shown in Figure 3 (Supply Chain Council (SCC) 2017). The top-level supply chain configuration is modelled to the detail level 1 and 2 defined by SCOR to describe the supply chain actors' goals, responsibilities and process categories. For each actor or stage, key supply chain processes and sub-processes are modelled to the detail level 3 and 4 defined by SCOR and to be ultimately represented in executable BPMN models which could be used to monitor, improve or simulate supply chain processes and performances.

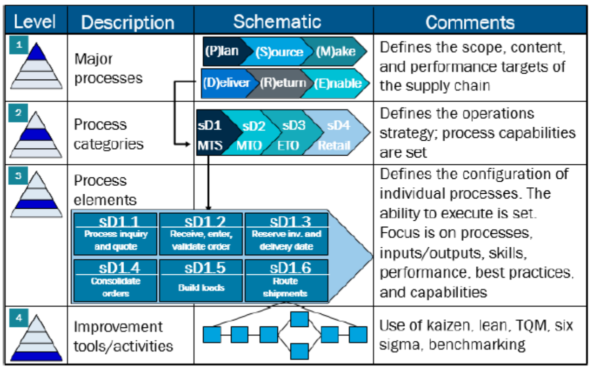

Figure 3: Hierarchical process model defined by SCOR Source: (Supply Chain Council (SCC) 2017)

Furthermore, to incorporate the performance aspect of the supply chain model, several items from SCOR are chosen to be integrated into the supply chain processes as performance goals for the modelled system. As it will be too complex to implement all performance factors of the SCOR standard, only some of the cost and other matrix related to sourcing and delivery of products and the practice of just-in-time production (JIT) are included in this demonstration model. The reason to emphasize those aspects is that the cases from the pilot project particularly highlighted the challenges of the mismatch between the moments in demolition and construction projects and the increased cost and risk factors due to the increased logistics operations for remanufacturing. The performance indicators are embedded into the BPMN task elements for the evaluation stage of the project. Table 1 shows examples of the performance indicators, selected from SCOR 12.0, to be considered in this demonstration model.

Table1: Performance indicators taken from SCOR

SCOR	Name	Parameters
CO.3.16	Cost to Source Return	On-site treatment and storage cost
CO.3.17	Cost to Deliver Return	Reverse logistics cost to remanufacturer
CO.3.15	Order Delivery Cost	Transportation to construction site
BP.1.10	JIT production	Time of warehousing for products
…	…	…

As the core back-end structure of the model is defined in BPMN, the processes, tasks and required input/output resources are carefully modelled according to the structure defined by SCOR. For the Level 1&2 model, the supply chain for the remanufacturing process consists of four main stakeholders, the project coordinator (often the main contractor), the demolition contractor (urban miner) for project A, the remanufacturer (factory) and the building contractor for the new project B. In this case, the main configuration of the supply chain processes includes project planning, conducting urban mining, delivery to remanufacturer, remanufacturing, delivery to construction site, installation on site. For the Level 3&4 model, sub-processes are created as BPMN tasks to be assigned to the supply chain actors and are detailed for specific operations. The BPMN orchestration model is used to connect the tasks and information flows between different actors. As the remanufacturing supply chain follows a sequential order and the different actors are coordinated as sub-processes of a single project, the model type is suitable for demonstrating the overall supply chain configuration.

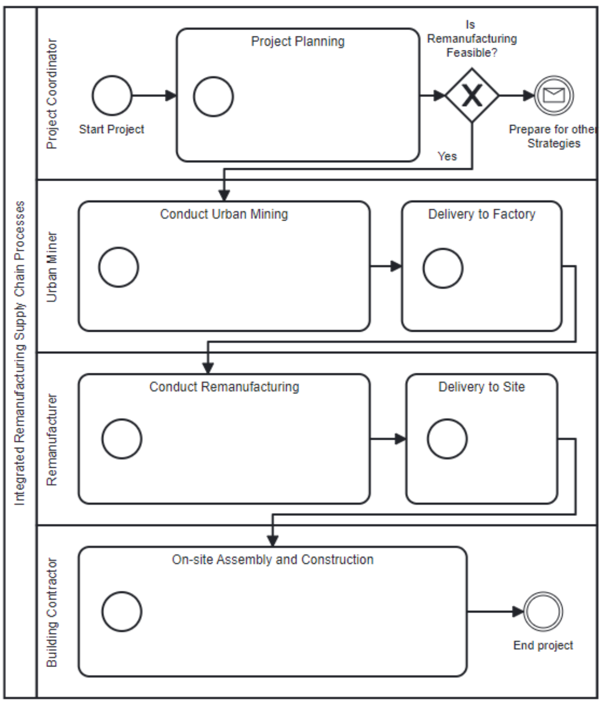

Figure 4: illustration of the main task flows in BPMN

Figure 4 illustrates how the three actors who are responsible for the production processes are controlled by a single point of coordination, which is in this case, the main contractor. Nevertheless, the orchestration model is not fully representative of the real timeline of production. as the four main actors conduct their activities simultaneously and the spatial-temporal coordination between those actors is much more complex than the diagram shows. In this study, the inter-organizational communication between the detailed sub-processes is left out for simplification. The main actors and key processes shown in this overall process diagram is a representation of the detail level 1&2 SCOR process model. The intent wasn't to strictly adhere to the pattern of SCOR for all detailed process definitions but instead to leverage the method and its principles to showcase a proof of concept in remanufacturing operations.

Based on the abovementioned supply chain structures, main process configurations and performance indicators the final BPMN model with detailed sub-tasks is done using Camunda modeler. By using the Camunda API for development, it is possible to attach forms or back-end JAVA classes to certain categories of tasks in the model. Thereby, the supply chain actors are given the possibility to interact with the model through input/output parameters and pre-defined calculations based on the data. Furthermore, the process model could also be executed via the "Deploy" icon within the Camunda portal, and to be accessed by actors through the task list in a web portal interface. More possibilities are allowed by the software architecture of the Camunda API as shown in the diagram Figure 5.

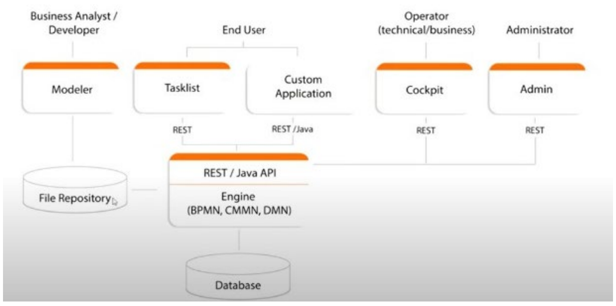

Figure 5: Camunda software architecture, source: (Techbuzz Blog 2022)

Results and Discussion

In this demonstration case, the project-based process of remanufacturing of wooden and glass façade elements is used as both the reference to model the supply chain structure, and also as the application example for potential model utilization. A process-centric model based on the real case is made because most supply chain models without real-world reference will be often quite abstract and could not possibly depict the complexity of processes involving multiple actors and dynamics in CE driven construction activities. On the other hand, the remanufacturing of building products is becoming a more popular and repeated practice in the Dutch construction industry, and the model could potentially be a reference model for other projects similar to the selected case.

Therefore the model is both case-informed and industry-wide generalizable.

The model demonstrates how the circular CSCM operations are modelled as a process based supply chain to achieve more 'maturity' in the form of an integrated supply chain system. The modelling procedure is based on the SCOR standard and BPMN. The execution of the BPMN process is done using the Camunda API which enables web-based user interfaces (UI). It could be accessed by different supply chain stakeholders to create input information and get insights into the supply chain operations in real time. The screenshot in Figure 6 shows how the stakeholders' can login the UI to get access to the executed processes and how the coordinator starts the BPMN process in his/her own dashboard. Despite incorporating limited quantitative data from the real project, the model comprehensively captures the processes for remanufacturing of the construction products in the case.

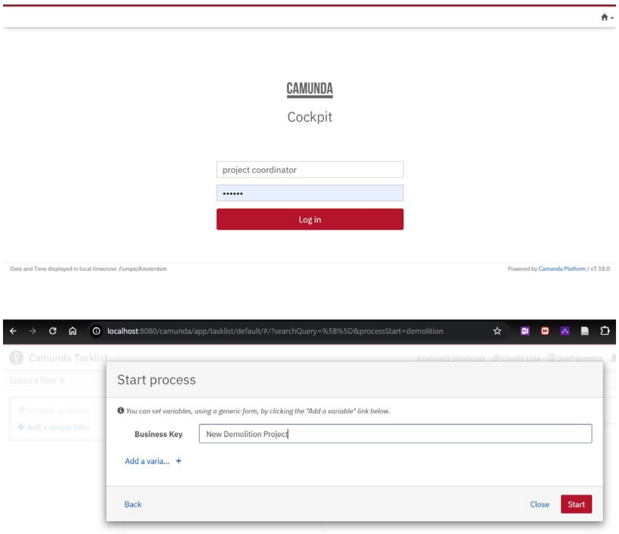

Figure 6: screenshots of the login page and start process

Afterwards, the integration of task parameters and performance indicators is enabled in this model through the Camunda API. This is achieved by creating forms in the Camunda web portal that gets input of variables for the setting of parameters of the model. For example, the transportation distance between the demolition project site, the manufacturer and the new project site; as well as the storage capacity for the locations. Those spatial and resource factors are required to make informative logistics planning between the project sites. As the new construction project may start much later than the deconstruction of the old building, the temporal dimension within the model is also crucial. Whether the schedule of different projects could fit into the resource planning, will drastically influence the performance outcomes such as JIT production and logistics cost. Therefore, the scheduled time of deconstruction, remanufacturing and new construction, are also included as model data and are acquired by the coordinator when initiating the projects. In this way, the model could already provide assumptions of logistics cost and JIT performance scores before going through the other processes. This demonstrates the prediction and simulation potential of the BPMN model that supports decision making before the execution of real processes. With the models and defined tasks, actors, and forms in place, the process can be "deployed" through the web portal. Beginning at the portal's "Start the Project" option, execution aligns with the process model.

In this demonstration case, the coordinator is able to check the feasibility of remanufacturing based on the basic input data about the project, while feasible, the process will be continued to initiate the multi-actor coordination for remanufacturing processes. In this model, the different actors will conduct detailed operations of the sub-processes that are pre-defined in the BPMN. Figure 7 shows screenshots of part of the executable BPMN model with embedded feasibility check for the selected R strategy, Arrow a highlights the tasks where the coordinator put in plannings and get results for feasibility simulation. Arrow b highlights the form interface for step by step data input of logistics information. Arrow c highlights the demonstration results as decision support reference for continuing the remanufacturing processes. In this model, the estimated cost to conduct RL of recovered products and deliver the new products, as well as the score for JIT production (logistics resource utilization) is calculated. The design intention of the model based tool is that the model could then integrate the different actor's detailed operational data and provide more accurate assumptions of the performance in real project timeline. However, as this study is a conceptual demonstration, the functions are not fully detailed to be tested in real projects. Different functionalities that are demonstrated in this study, and possible future development directions are listed in Table 2.

Table 2: Covered functionalities by the tool and progress of development by this study

Functionality & Applications	Progress
Standardize supply chain models of CE strategies in construction with SCOR	Demonstrated
Model supply chain processes in easy-to-understand manner (BPMN)	Demonstrated
Represent integration of different actors in the supply chain system	Demonstrated
Simulate supply chain cost and JIT delivery possibility	Partial Demo.
Allow actors to input and gain key data for model update	Partial Demo.
Simulate and compare performance of different CE strategies (e.g. reuse vs. remanufacturing)	To be Developed
Simulate different configurations of as-is and to-be models	To be Developed

The demonstration of the tool suggest multiple potential areas to apply the model-based tool to CE-driven construction activities incorporating the simulation and predictive capabilities: (1) to improve cost and planning of different CE strategies and reverse logistics operations by including the detailed process cost and time predictions in the task elements in BPMN. (2) to compare as-is and to-be scenarios when designing supply chain re-configuration (Trkman et al. 2007). (3) to continuously monitor supply chain performance by collecting key performance data from more projects where the tool is used.

centric approach brings the model one step closer to real life applications, because it brings more ease of interaction between stakeholders and the model through a process-automation software platform that executes the process model to refined details. This study has selected the commercial software Camunda platform for development and demonstration, similar tools are also available such as Bonita Soft or Eclipse.

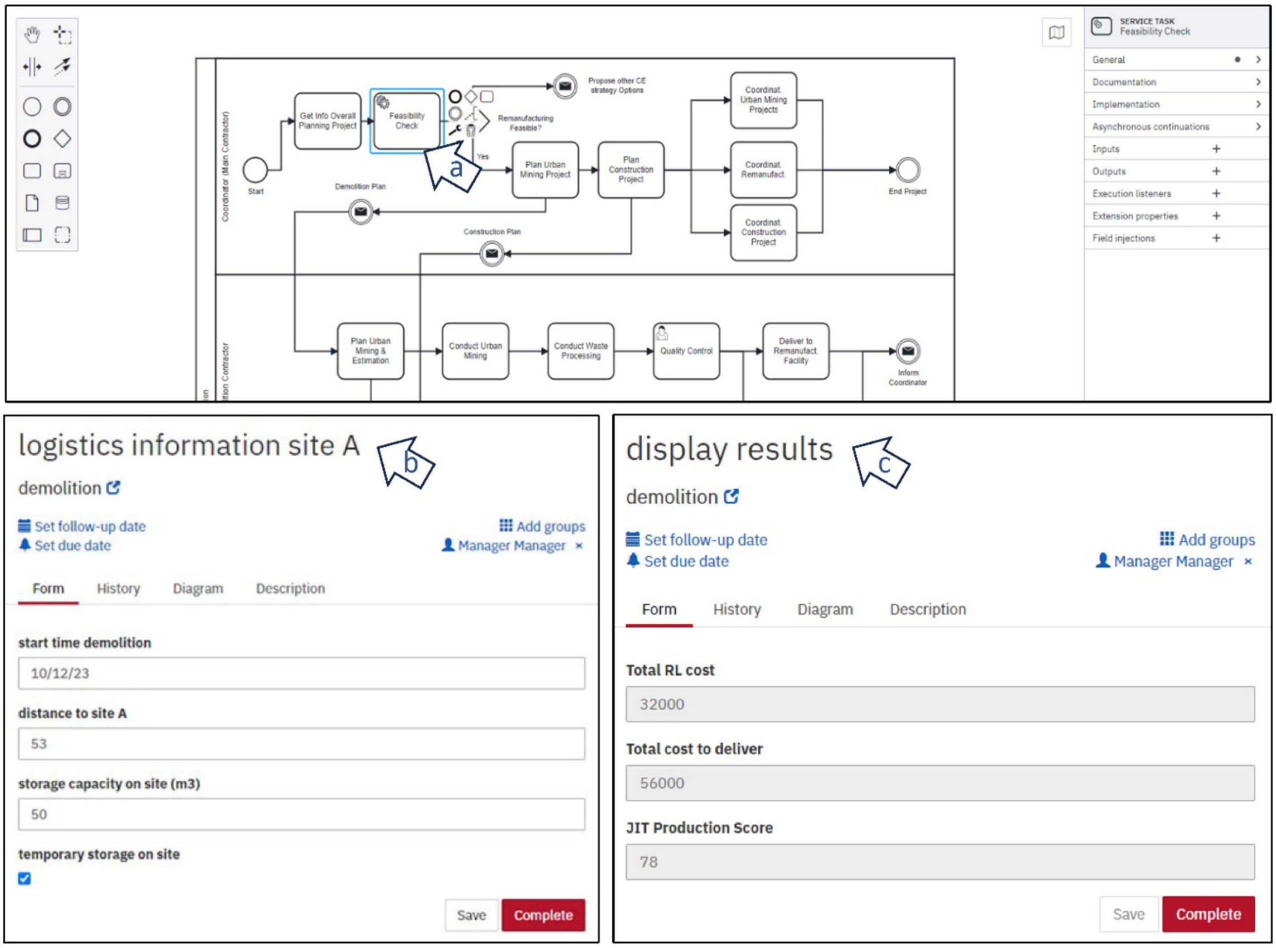

Figure 7: Example BPMN process diagram and the UI for input/ output data

Through post design workshops with experts in construction management from higher education, technical specialists from façade manufacturing companies and consultants for information systems, the tool for process centric supply chain modelling is further evaluated. The innovative approach and potential usefulness of the process simulation and execution tool for CE driven goals have been acknowledged by the potential users. The experts also highlighted that the feature of including cost estimation and monitoring in BPMN will be useful for making more informed decisions about CE in construction. More desired features could be added in the future to the model such as LCA / environmental impact of the processes.

The tool provides the simplicity of having supply chain stakeholders involved to have access to the processes, tasks and relevant parameters in one user interface (UI) that is executed with the BPMN. Compared to other methods to model supply chain operations, this process-

One clear limitation of this study is that it is based on tools and standards previously applied mainly to manufacturing, which contains many features that are complex to apply to the project-based supply chain systems in the construction industry and circular economy. And further, the compatibility of the models with the different CE concepts and strategies is also limited. Moreover, the supply chain model tackles only one R-strategy of CE in practice. The more ambitious visions of CE driven supply chain models that may incorporate multiple R strategies are yet to be developed and tested.

Conclusions

The study proposes a process centric circular supply chain model for construction products based on the concept of process maturity in supply chain integration (supported by the SCOR standard) and the BPMN modelling language. It is a proof of concept to demonstrate how such models may act as new tools to improve supply chain integration for CE driven strategies in construction. In this case, the project case of remanufacturing façade elements is taken for the demonstration of their capability to coordinate supply chain operations beyond traditional construction and contractor-supplier coordination.

The model aims to capture the details of the remanufacturing supply chain for construction products, focusing on wooden frame and glass components recovered from a demolition site which are repurposed for a new project in Amsterdam. Four main actors are involved in the modelled case, the coordinator, the demolition contractor for the old building, the remanufacturer and the builder of the new project. For each actor, key supply chain processes and sub-processes are modelled according to the four hierarchies structure defined by SCOR and translated in BPMN for digital representation. Performance metrics such as JIT production and logistics costs from SCOR are integrated in the evaluation matrix for the supply chain model. Afterwards, the BPMN based model is then further developed into a tool for the design of supply chain collaboration, with a web-based interface using the Camunda platform. Through Camunda API, the model enables execution of BPMN tasks and allows for model deployment through a web portal for easy access by supply chain actors. It demonstrates the exchange between supply chain actors and the process model through a range of forms and parameters. Besides, the tool emphasizes the model's predictive and simulation potential, aiding key decision-making points before actual process execution. The study shows how process models are able to capture the complexities of interaction between demolition, remanufacturing and re-construction projects in CE, which traditional CSCM models and tools have not yet effectively addressed. Additionally, the interactive UI developed with Camunda API in this case, shows more multi-stakeholder decision support and collaboration possibilities beyond the process model itself, that may potentially accelerate the adoption of CE strategies by supply chain actors and help in upscaling the practices with more empirical evidence in future cases.

The key innovative feature of the tool is that it applies more mature supply chain process models from the manufacturing industry to cases in circular construction, and utilizes the advanced features from a BPMN software for process simulation and execution. The study tackles an important gap in CE and CSCM literature, which is the lack of understanding and experiments on process integration that connects the overall CE initiatives and strategies with the actual outcome of CE performance in construction supply chains. The study contributes to the methodological advancement for future research to explore modeling techniques for circular construction supply chains, highlighting the importance of standardization of supply chain processes and BPMN's suitability for process execution. By introducing a pilot case of façade element remanufacturing also demonstrates the applicability of the proposed framework to more practical situations, which may lead to more repetitive practices of such CE driven strategies in future construction projects.

The current model in this tool is still limited by the lack of more real-world project data to enhance its functions and improve the model configuration to track and predict the performance more accurately. Future works shall focus on elaborating the process models to suit more practical scenarios and further explore the information models and data integration with existing systems which may support more advanced process execution in more complex cases. Moreover, the simulation approaches of the process model shall be further developed to include more CE scenarios and more comprehensive performance indicators such as carbon emissions and environmental impact.

Authors' Contribution

First draft, L.D.; conceptualization, L.D. and T.W.; tool development, L.D. and T.W.; project coordination, supervision, W.G. and P.C.; review and editing, T.W. and W.G.;

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References

Adi Wijaya, P., and R. Armyn Machfudiyanto. 2023. 'Conceptual Framework of Green Supply Chain Management Strategy Selection in the Indonesian Construction Industry'. in Vol. 405.

Akinade, O. O., and L. O. Oyedele. 2019. 'Integrating Construction Supply Chains within a Circular Economy: An ANFIS-Based Waste Analytics System (A-WAS)'. *Journal of Cleaner Production* 229:863–73. doi: 10.1016/j.jclepro.2019.04.232.

Chen, Qian, Haibo Feng, and Borja Garcia de Soto. 2022. 'Revamping Construction Supply Chain Processes with Circular Economy Strategies: A Systematic Literature Review'. *Journal of Cleaner Production* 335. doi: 10.1016/j.jclepro.2021.130240.

Chen, Zixuan, and Ahmed W. A. Hammad. 2023. 'Mathematical Modelling and Simulation in Construction Supply Chain Management'. *Automation in Construction* 156:105147. doi: 10.1016/j.autcon.2023.105147.

Cheng, Jack C. P., Kincho H. Law, Hans Bjornsson, Albert Jones, and Ram D. Sriram. 2010. 'Modeling and Monitoring of Construction Supply Chains'. *Advanced Engineering Informatics* 24(4):435–55. doi: 10.1016/j.aei.2010.06.009.

Di Maria, Eleonora, Valentina De Marchi, and Ambra Galeazzo. 2022. 'Industry 4.0 Technologies and Circular Economy: The Mediating Role of Supply Chain Integration'. *Business Strategy and the Environment* 31(2):619–32. doi: 10.1002/bse.2940.

Ding, Lu, Tong Wang, and Paul W. Chan. 2023. 'Forward and Reverse Logistics for Circular Economy in Construction: A Systematic Literature Review'. *Journal of Cleaner Production* 388:135981. doi: 10.1016/j.jclepro.2023.135981.

Eisner, Michael. 2021. 'Orchestrating People and Systems with BPMN 2.0'.

Ellen MacArthur Foundation. 2013. *Towards the Circular Economy*.

Eriksson, P. E. 2010. 'Improving Construction Supply Chain Collaboration and Performance: A Lean Construction Pilot Project'. *Supply Chain Management* 15(5):394–403. doi: 10.1108/13598541011068323.

Farooque, Muhammad, Abraham Zhang, Matthias Thürer, Ting Qu, and Donald Huisingh. 2019. 'Circular Supply Chain Management: A Definition and Structured Literature Review'. *Journal of Cleaner Production* 228:882–900. doi: 10.1016/j.jclepro.2019.04.303.

Hussein, Mohamed, Abdelrahman E. E. Eltoukhy, Ahmed Karam, Ibrahim A. Shaban, and Tarek Zayed. 2021. 'Modelling in Off-Site Construction Supply Chain Management: A Review and Future Directions for Sustainable Modular Integrated Construction'. *Journal of Cleaner Production* 310:127503. doi: 10.1016/j.jclepro.2021.127503.

Incorvaja, D., Y. Celik, I. Petri, and O. Rana. 2022. 'Circular Economy and Construction Supply Chains'. Pp. 92–99 in.

Koolwijk, Jelle Simon Jowan, Clarine Joanne van Oel, Johannes Wilhelmus Franciscus Wamelink, and Ruben Vrijhoef. 2018. 'Collaboration and Integration in Project-Based Supply Chains in the Construction Industry'. *Journal of Management in Engineering* 34(3):04018001. doi: 10.1061/(ASCE)ME.1943-5479.0000592.

Koskela, Lauri, Ruben Vrijhoef, and Rafaella Dana Broft. 2020. 'Construction Supply Chain Management through a Lean Lens'. Pp. 109–25 in *Successful Construction Supply Chain Management*. John Wiley & Sons, Ltd.

Lockamy, Archie, and Kevin McCormack. 2004. 'The Development of a Supply Chain Management Process Maturity Model Using the Concepts of Business Process Orientation'. *Supply Chain Management: An International Journal* 9(4):272–78. doi: 10.1108/13598540410550019.

Migliore, M. 2019. 'Circular Economy and Upcycling of Waste and Pre-Consumer Scraps in Construction Sector. The Role of Information to Facilitate the Exchange of Resources through a Virtual Marketplace'. *Environmental Engineering and Management Journal* 18(10):2297–2303.

Nasir, Mohammed Haneef Abdul, Andrea Genovese, Adolf A. Acquaye, S. C. L. Koh, and Fred Yamoah. 2017. 'Comparing Linear and Circular Supply Chains: A Case Study from the Construction Industry'. *International Journal of Production Economics* 183:443–57. doi: 10.1016/j.ijpe.2016.06.008.

Neuhäuser, Thomas, Johannes Dimyadi, Christian Johannes Eckart, Franziska Wagner, Andrea Hohmann, Robert Amor, and Rüdiger Daub. 2023. 'Systematic Integration of Building Information and Simulation Models for the Automated Evaluation of Factory Layout Variants'. Pp. 0–0 in Vol. 4, *Computing in Construction*. European Council on Computing in Construction.

O'Brien, W., Kerry London, and R. Vrijhoef. 2004. 'Construction Supply Chain Modeling : A Research Review and Interdisciplinary Research Agenda'.

O'Brien, William, Kerry London, and Ruben Vrijhoef. 2002. 'Construction Supply Chain Modeling: A Research Review and Interdisciplinary Research Agenda'. *Proceedings IGLC 10.*

Supply Chain Council (SCC). 2017. 'Supply Chain Operations Reference Model (SCOR) Version 12.0'.

Techbuzz Blog, dir. 2022. *Camunda Architecture | TECH BUZZ BLOGS*. TECH BUZZ BLOGS.

Teixeira, Kellyn Crhis, and Milton Borsato. 2019. 'Development of a Model for the Dynamic Formation of Supplier Networks'. *Journal of Industrial Information Integration* 15:161–73. doi: 10.1016/j.jii.2018.11.007.

Trkman, Peter, Mojca Indihar Štemberger, Jurij Jaklič, and Aleš Groznik. 2007. 'Process Approach to Supply Chain Integration'. *Supply Chain Management: An International Journal* 12(2):116–28. doi: 10.1108/13598540710737307.

Vrijhoef, Ruben, and Lauri Koskela. 2000. 'The Four Roles of Supply Chain Management in Construction'. *European Journal of Purchasing & Supply Management* 6(3–4):169–78. doi: 10.1016/S0969-7012(00)00013-7.