Requirements Analysis for a Digital Twin to Increase the Resilience of Multimodal Corridors: A Case Study in the Twente Region

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Abstract. The drought in 2018 and 2022 in The Netherlands caused a reverse modal shift from inland waterways to road transportation within the Twente region in the eastern part of the country. These drought periods resulted in delivery delays, disruption of planning and operational processes, and reduced production capacity, affecting the entire logistics ecosystem in the region, consisting of inland ports and container terminals, logistic and production companies using the ports, and policymakers. As a result, these stakeholders are looking for solutions that increase the resilience of operations in the Twente corridor, helping them prepare, react, recover, and learn from disruptions. To improve the resilience, a digital twin is being developed to monitor the corridor's activities, performance, and infrastructure in real-time, providing alerts and useful information in the face of disruptions. This paper reports the results of the requirements analysis for the development of the digital twin, including the validation and prioritization by involved stakeholders. Although the research focuses on the Twente region, the program of requirements can be reused as a starting point for other multimodal corridors that face similar challenges and disruptions.

Keywords: Multimodal Corridor · Inland Waterways · Resilience · Digital Twin · Requirements

1 Introduction

The logistics industry has always been important to the Dutch economy. Many products from abroad are transported through the main ports in the Netherlands to the inland regions of Europe and other regions of the world, and vice versa [14]. Often, goods are transported in multimodal corridors, that is, through integrated transport networks that combine a primary mode of transport with additional modes, such as inland waterways plus roads and rails [19].

Climate change has caused significant pressure on multimodal corridors in recent years. It has led to droughts, flooding, infrastructure failures, and downtime, revealing the vulnerability of multimodal corridors and significantly impacting their performance, including negative impacts on direct stakeholders. These disruptions also affected multimodal transport in the Twente region, causing problems in many aspects, as can be seen in the example of the reverse modal shift caused by drought in this region in 2018 and August 2022[3], which resulted in a considerably larger number of trucks on the roads. Vulnerabilities in multimodal corridors have serious consequences and need to be addressed. It is important to note that these problems are not unique to the Twente region; other European multimodal corridors have experienced similar challenges [21].

Port authorities, terminal operators, transport operators, production companies, recycling companies, and policymakers are interested in improving the resilience of the operations of this multimodal corridor. Resilience here means anticipation through preparation, detecting risks and vulnerabilities as early as possible, efficiently recovering from disruptions, and returning to normal operations as fast as possible, analogous to the definition of Park et al. [15], who describe resilience as the capacity to adapt to changing conditions without catastrophic loss of form or function [2].

Digital Twin (DT) technology has emerged as a promising way to increase the resilience of logistics systems, offering real-time visibility of physical supply chains in a digital environment combined with advanced analytics, simulation models, and optimization techniques [13]. When applied to multimodal transport, DT allows stakeholders to collaboratively monitor the operations and performance of the multimodal corridor, simulate various scenarios and interventions, predict disruptions, and optimize performance dynamically. What makes DT especially attractive for solving the problems previously described is that DTs not only help monitoring the real environment to make predictions and support decision making, but also allow real-time interventions in the physical world based on the monitoring results.

In software development in general, and in the development of DTs in particular, requirements specification, validation, and prioritization play an important role. Requirements specification includes capturing the needs of all involved stakeholders, considering their preferences, and resolving possible conflicts regarding these requirements. Requirements validation is used to determine the correct requirements, avoiding inconsistencies, incompleteness, inaccuracies, and other defects, and to check if the requirements can properly guide the design and implementation of the system. It reduces the risks associated with software projects by helping to detect and correct errors that may occur unintentionally [20]. Requirements prioritization is the process of defining the relative importance of the requirements for the stakeholders. It is a key step in making critical decisions that enable the software under consideration to function as expected and increase its economic value. Prioritizing requirements before architectural design and coding will significantly help implement the important software components earlier [1]. These techniques assist in implementing the system based on the desired features of the stakeholders and according to schedule and budget.

[3] `https://www.rijkswaterstaat.nl/nieuws/archief/2022/09/droogte-en-laagwater-belemmeren-werkzaamheden-twentekanalen`

Goal-Oriented Requirements Engineering (GORE) is an approach to identify, analyze, and refine stakeholders' goals to derive system requirements [11]. It focuses on understanding the "why" behind the elicited system functionalities, ensuring that the developed system aligns with organizational objectives and stakeholder intentions. Typically, GORE is hierarchically structured by deriving high-level objectives from stakeholders, which are then decomposed into specific sub-goals [11]. Multiple frameworks for goal-oriented requirements engineering exist, e.g., KAOS [16] and *i** [5]. Our work adopts *i**, which allows the representation of actors (i.e., stakeholders), along with their goals and tasks, as well as how these actors depend on each other to fulfill their goals, execute their tasks, or obtain information/resources. Modeling dependencies allows early identification and assessment of potential conflicts or trade-offs between stakeholder goals.

This paper presents the results of a requirements engineering process performed for the DT under development to increase the resilience of multimodal corridors, focusing specifically on the Twente corridor. For that, we interviewed nine stakeholders of the given logistics ecosystem to grasp their needs and wants. Next, we combined the use of a goal-oriented requirements analysis and a requirements table to present the result of the requirements specification phase in detail. Finally, we validated and prioritized these requirements by conducting a survey with the stakeholders interviewed to check if the specified requirements are correct and what their priorities are about the functionalities of the system.

The remainder of this paper is organized as follows. Section 2 discusses the background information and related works on DTs in the logistic sector; Section 3 presents the requirements engineering method applied in this work; Section 4 focuses on our DT requirements, presenting the developed goal models and the requirements table resulting from requirements specification, validation, and prioritization; and Section 5 concludes this paper.

2 Digital Twins in Logistics

A DT is a virtual representation of a physical object/system that allows for simulation, monitoring, and performance optimization using AI and other simulation techniques [10]. A DT is based on a fully automated data flow and bi-directional interaction. In other words, changes in physical objects result in changes in digital objects and vice versa.

DTs in logistics can improve the resilience of multimodal logistics by improving the flexibility and adaptability of complex supply chain networks through multiple means. First, DTs allow real-time monitoring and predictive analytics by integrating diverse data sources such as weather forecasts, IoT sensor data, logistics planning systems, and infrastructure data [4,9]. Visualization and analytics help diagnose operations problems, detect inefficiencies, and anticipate failures [6,17]. Furthermore, mitigation strategies can be developed by simulating disruption scenarios (e.g., low water levels affecting inland shipping) so that stakeholders can make proactive decisions to maintain supply chain continuity [18,7]. Second, conventional logistics rely on static modal planning, likely resulting in infeasible plans once disruptions occur. A DT can form the basis for dynamic adjustment of decision-making based on real-time conditions [12,8]. Predictions and prescriptive analytics allow rapid application of alternative transport plans, such as rerouting cargo or adjusting inventory levels, thereby reducing costs and optimizing resource utilization [3].

Several DT projects have been initiated within the context of multimodal logistics, e.g., the DT Fairway Corridor (DTFC)[4] or the TRANS2[5] projects that focused on the Rhine-Maas corridor. These projects have produced relevant research output and prototypes, providing insights for developing DTs for multimodal corridors. Moreover, Busse et al. [4] focuses on DTs for multimodal supply chains, including waterways. Other research focuses on the design of DTs for logistics more generally, e.g., smart cities [18,12] and supply chains [9]. More conceptual works offer reference models and ontologies for architecting DTs or merely review the literature [8,6,9,7]. These related works only present DT requirements at a high-level, and to the best of our knowledge, there are no publications detailing the requirements engineering process used in developing a DT in the logistics sector.

3 Applied Requirements Engineering Method

This research follows four phases: Requirements Elicitation, Goal Modeling, Requirements Specification, and Requirements Validation and Prioritization. The work has been carried out by three requirements analysts (analysts, for short).

For **Requirements Elicitation**, requirements analysts A and B conducted interviews with nine members of the Twente corridor ecosystem. These were semi-structured interviews focusing on the main challenges faced by the companies, and their goals and requirements with respect to the DT. The analysts were also open to hearing any additional recommendations for improving the resilience of multimodal transport operations. The results of these interviews were documented by analyst A.

After the interviews, analyst B proceeded to the **Goal Modeling** phase, based on a synthesis of the information provided by all stakeholders. Our goal models describe the high-level requirements using *i** modeling constructs. Two sets of models have been created: model set (i) representing the current situation (*as-is models*), concerning stakeholders main goals and information needs and how they depend on each other to obtain their required information; and model set (ii) modeling the future situation (*to-be models*) considering the DT under development and how this affects the previous dependencies. These models were validated with the support of a Requirements Engineering expert and a multimodal transport expert who work closely with the members of Twente corridor ecosystem.

[4] `https://www.fairwaydanube.eu/`

[5] `https://www.deltares.nl/en/expertise/projects/trans2-for-more-future-proof-waterways`

The goal models offer a preliminary understanding of the stakeholders' high-level requirements, but to allow implementation, these requirements are refined during a **Detailed Requirements** phase, conducted by requirements analyst C. This phase started with an inspection of the interview documentation. Since each interview was documented separately, the first result of the inspection was the creation of a requirements table per stakeholder. These requirements tables were then integrated, resulting in a unique initial requirements table for the DT. This process involved sorting out common or similar requirements among the various stakeholders. Each line of the initial requirements table corresponds to a functional or a non-functional requirement for the DT.

Finally, requirements analyst C conducted a survey[6] based on the requirements table and submitted it to the nine interviewed stakeholders for **Validation and Prioritization**. Each survey question corresponds to one requirement from the table, to be rated by the respondents following a 4-point Likert scale, ranging from 1 to 4, regarding the need of the corresponding requirement (following the established requirements prioritization procedure). In this way, stakeholders could express their priority level for each requirement. At the end of the survey, an open question collected new requirements that were not found in the initial requirements table. This phase resulted in a final requirements table with an added column expressing the requirements' priorities (averaged from the responses collected via the survey).

4 Goal Models and Requirements

4.1 Goal Models

The goal models presented in this section represent the high-level requirements of the DT stakeholders. Fig. 1 depicts a model of the current situation, showing how the different stakeholders currently depend on each other for information (represented as $i*$ resource dependencies). For example, the LOGISTIC COMPANIES currently rely on the TRANSPORTERS to have information about *load capacity*, *type of transport*, *transportation cost*, and *availability*. The LOGISTIC COMPANIES depend on information from the GOVERNMENT WATER MANAGEMENT DEPARTMENT about the *infrastructure (bridges, water locks)*, *road work/blockages* and *traffic congestion*. The ports of Twente and Zwolle and the Transporters have their own information needs, for which they also depend on other actors.

Looking at the number of mutual dependencies between the actors in the model of Fig. 1, one can understand the reason for some inefficiencies. Each dependency on information requires constant and direct interactions between the actors. For instance, the LOGISTIC COMPANIES needs information from the GOVERNMENT WATER MANAGEMENT DEPARTMENT to get informed about possible obstructions and congestion on the desired route. To decide which transportation modality to use and which transporter to hire to transport the goods,

[6] This survey may be found at `https://forms.gle/i8gH5yaS64KK7y82A`

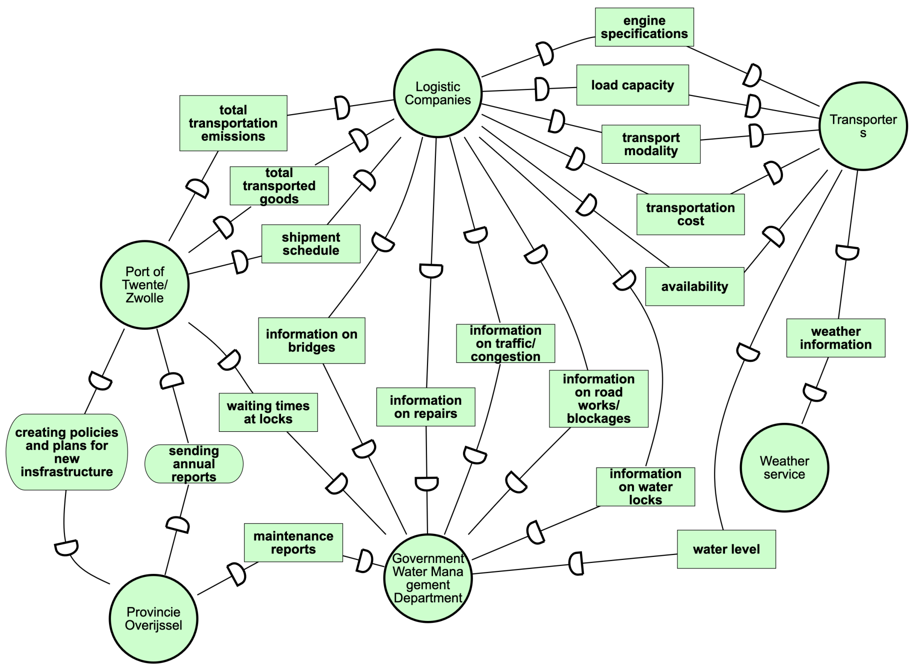

Fig. 1. Goal model depicting how stakeholders currently depend on each other to gather information

information from the TRANSPORTERS is needed. The way information is currently gathered and processed often hinders the LOGISTIC COMPANIES's goal of *fast decision-making*. For example, having to *contact transporters directly* and *needing information on infrastructure blockages* end up delaying decisions and making the logistic process less efficient.

All stakeholders have been at the center of the DT requirements engineering process. In general, they expect that the development of the DT will provide the required information more promptly and consistently so that they may take proactive action in case of imminent disruptions, improving their decision-making efficiency and the multimodal corridor's resilience.

The goal model in Fig. 2 depicts how the DT can be included in this setting to make predictions, facilitate real-time monitoring of the multimodal corridor, and provide relevant information to the stakeholders in need. As can be noted, the DT has the main goal of *optimizing logistics and supply chains*. For that, it must accomplish several subgoals, such as *providing the best modality of transport*, *providing suggestive actions against reverse modal shift*, *providing overview of historical data*, *assessing the performance of the canals*, and *simulating scenarios*. To accomplish these subgoals, the DT must execute the following tasks: *provide an overview of available transporters*, *predict water levels*, *predict congestion*, *actively monitor the canals*, and *monitor operations of the infras-*

tructure. The model shows new information dependencies, now going from the DT to the Transporters and to the Government Water Management Department. Moreover, it shows how the information needs of the Ports of Twente/Zwolle and the Logistic Companies are fulfilled by the DT in the form of performance reports and historical analysis. Since a Digital Twin works by connecting the digital and real worlds in an automated way, previous inefficiencies related to the multiple dependencies and constant interaction of stakeholders will be alleviated (see again the discussion related to Fig. 1.

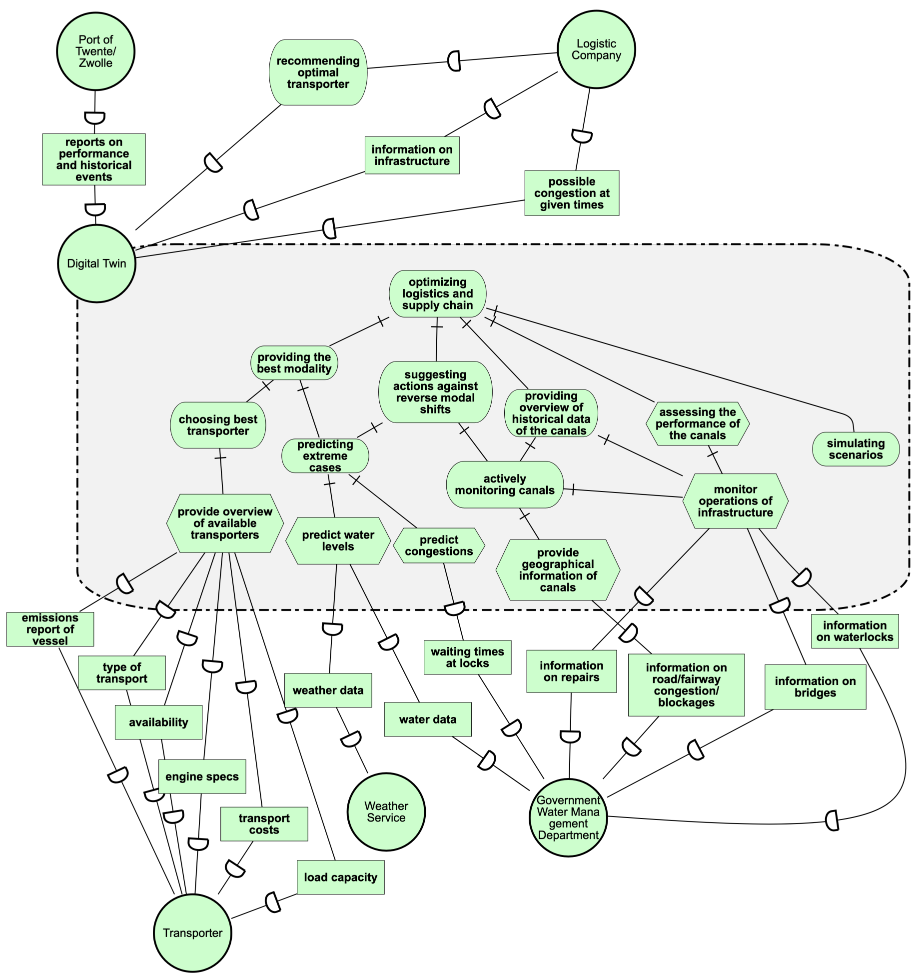

Fig. 2. Future dependencies considering the development of the DT, along with the system's internal view

4.2 Validated and Prioritized Requirements

As mentioned in Section 3, requirements were collected through interviews with the involved stakeholders, documented and inspected to enable requirements specification. A survey was conducted to validate and prioritize the specified requirements. Unfortunately, only three of the nine interviewed stakeholders responded to the survey. Thus, the results reported here are preliminary and subject to further validation rounds.

Table 1. "Environmental Information" view of the Final Requirements Table

ID	Requirements	Comment	Priority
	Water information		
1.1.1	System displays real-time water level, depth and flow	IJssel River, Twente Canal, around locks and bridges	4
1.1.2	System alerts users when the water level is lower/higher than a certain level	Such as when the IJssel River water level is lower than possible water pumping water level, it alerts users	4
1.1.3	System calculates and displays predicted water level/depth for next several weeks	Based on past data, weather forecast, etc.	4
1.1.4	System alerts users when predicted water level/depth is lower/higher than a certain level	Such as When the predicted IJssel River water level is lower than possible water pumping water level, it alerts users	4
1.1.5	System allows users to set specific conditions to activate the alarm	Such as: Give an alert when the water level is lower than 8 meters	3
1.1.6	System displays water temperature		2
	Weather information		
1.2.1	System displays weather forecast	Including temperature, wind, etc.	2
1.2.2	System alerts users when adverse weather is forecasted/observed		2

Together Table 1 and Table 2 provide a partial view of the Functional Requirements Table. The complete table is not presented here due to page limitations but can be found in the project's GitHub folder[7]. The tables are organized with the following columns: ID (for the requirement identifier), Requirement (short description of the requirement), Comment (additional comments about the requirement) and Priority (requirement priority level). The priority level score can be interpreted as follows: 4 ("Must have" the requirement); 3 ("Should have" the requirement); 2 ("Could have" the requirement); N ("Will not have" the requirement); and S (Suggested by stakeholder in response to the survey).

[7] https://github.com/Sekai0011/Assessing-and-Prioritizing-the-Requirements-of-a-Digital-Twin-for-the-Port-of-Twente

Table 2. Partial "Operational Management" view of the Final Requirements Table

ID	Requirements	Comment	Priority
	Operational plan management		
2.1.1	System alerts users about the possible need to adjust the loading layer, capacity, and transport routes	Such as When the water level rises, the loading layer height needs to be adjusted because it may be caught by the bridge's maximum passing height limit when passing through the bridge. Based on water levels, vessel type, cargo loads, bridge height restrictions, malfunction on the route, etc.	4
2.1.2	System displays information on narrow and difficult waterways, obstructions on waterways, obstructions on transportation routes		4
2.1.3	System allows users to create and save operational plan	Transportation method (ship, truck, rail, and its type), route, scheduling, cargo handling operation plan, etc.	3
2.1.4	System allows users to modify/adjust the operational plan		3
2.1.5	System allows users to view the operational plan		3
2.1.6	System provides real-time estimated time of arrival, cargo status, and estimated time of plan completion	Based on transportation status	3
2.1.7	System calculates and suggests optimal transportation plan to transport destination	Based on distance, water conditions, road conditions, CO_2 emission and other various information on the transportation route	3
2.1.8	System calculates and suggests optimal scheduling and provides information such as optimal sailing speed	Based on vessels, canals, lock passage times, and a variety of other operational factors	3

The requirements table is classified into categories and sub-categories according to the type of information to which it refers. Table 1 contains the first two sub-catogories and Table 2 the third (see lines without ID value). An overview of all sub-categories is presented below:

– Water information: Requirements related to real-time information about water levels and predictions of water level fluctuations.

- Weather information: Requirements related to weather forecasts.
- Operational plan management: Requirements related to the operational plan.
- Ship information: Requirements for real-time ship monitoring and other ship-related information.
- Facilities management: Requirements related to canal facilities.
- Bridge and lock management: Requirements related to the infrastructure, i.e. bridges and locks, including their real-time status (functioning or blocked).
- Cost management: Requirements related to the tracking and optimization of transportation costs.
- Fuel/CO2 emission management: Requirements related to the tracking and optimizing of fuel consumption and CO2 emissions.
- Storage management: Requirements related to storage management.
- Communication channel: Requirements related to communication channels.
- Information hub: Requirements related to information providing platforms.
- Account: Requirements related to accounts within the system.
- Payment: Requirements related to the payment process at the canal facilities.

The five elicited non-functional requirements are the following: a) the system provides only reliable and accurate data; b) the system provides long-term, accurate water level forecasts with over 70% accuracy; c) sensitive information (e.g., vessel location, cargo information, etc.) is protected by a sophisticated security mechanism; d) the UI is understandable and actionable even for users without technical background; and e) the UI displays on smartphones, tablet, laptops and desktops.

The analysis of the survey results shows that 11 out of the 62 functional requirements received the highest priority 4, with high percentages in the *Water information* and *Bridge and lock management* requirement sub-categories. All five non-functional requirements received high priority values, either 4 or 3. We advise that the DT development starts from the functional requirements marked as 4 and progressively adds the functionalities in descending order with respect to the priority level. As for the non-functional requirements, we expect more non-functional requirements to arise during the development phases. Therefore, all should be observed from the start of the development.

The lowest rated requirement was *3.1: System allows users to manage inventory information for their warehouses*, and the only one marked as N in the table. Since the stakeholders did not find this requirement important, it can be removed from the table, and thus, such functionality will not be developed in the DT. Survey respondents proposed the following new requirements: *2.1.14: System provides comparisons based on water level predictions, by ship vs. truck or other transportation modalities* and *5.3.1: System provides 3D visualization simulation tool*. These new requirements have priority level score S.

5 Conclusion

In this paper, we reported on the requirements engineering process to develop a Digital Twin (DT) to improve the resilience of multimodal corridors. We focus on the case of the Twente region in The Netherlands. However, given that this problem is recurring in other European regions (and possibly in other areas of the world), we hope that this research serves as a starting point for developing DTs to improve resilience in multimodal transport, in general. In this context, the requirements we captured, analyzed, and validated can be reused to guide the development of DTs for other multimodal corridors, focusing on monitoring real-time data, making predictions, and providing timely information and actionable insights to different stakeholders so they can proactively mitigate risks and/or recover from climate-based or other types of disruptions.

We acknowledge the main limitation of the work, i.e., the number of participants in the requirements validation phase, which was a little over 30% of the total number of stakeholders consulted. To correct this, we hope to consult the remaining stakeholders in the near future. Given our experience so far, we expect that the list of requirements will remain more or less stable, but the prioritization level of each requirement may change. A few new requirements may possibly be suggested. Given that the stakeholders are of different types, including logistic companies, ports, policymakers, and production companies, we believe that the involved participants are representative of the DT's future users. Moreover, DT development is cyclic and we hope that in a new development cycle we will be able to involve more stakeholders, leading to a more consistent validation of the requirements.

Many of the elicited requirements regard what kind of processes should be monitored (e.g. changes in water level, transportation delays, etc.) and predicted (e.g. natural disasters and other disruptions). For that, the next development steps involve the implementation of algorithms and quantitative analyses techniques to fulfill such requirements.

This is still an ongoing project. The DT development cycle should proceed with the design, implementation and validation, possibly leading to several cycles before a complete version of the DT is ready for use. We will use the gathered requirements for prototyping, supporting requirements validation by allowing stakeholders to test the developed prototype. Our future research agenda comprises all the remaining DT development cycles.

References

1. Achimugu, P., Selamat, A., Ibrahim, R., Mahrin, M.N.: A systematic literature review of software requirements prioritization research. Information and Software Technology **56**(6), 568–585 (Jun 2014)
2. Bak, O., Shaw, S., Colicchia, C., Kumar, V.: A systematic literature review of supply chain resilience in small–medium enterprises (smes): A call for further research. IEEE Transactions on Engineering Management **70**(1), 328–341 (Jan 2023)
3. Bakhshi, S., Ghaffarianhoseini, A., Ghaffarianhoseini, A., Najafi, M., Rahimian, F., Park, C., Lee, D.: Digital twin applications for overcoming construction supply chain challenges. Automation in Construction **167**, 105679 (2024)
4. Busse, A., Gerlach, B., Lengeling, J.C., Poschmann, P., Werner, J., Zarnitz, S.: Towards digital twins of multimodal supply chains. Logistics **5**(2), 25 (2021)

5. Dalpiaz, F., Franch, X., Horkoff, J.: istar 2.0 language guide (2016)
6. Ferko, E., Bucaioni, A., Behnam, M.: Architecting digital twins. IEEE Access **10**, 50335–50350 (2022)
7. Ge, C., Qin, S.: Digital twin intelligent transportation system (dt-its)—a systematic review. IET Intelligent Transport Systems **18**(12), 2325–2358 (2024)
8. Irfan, M.S., Dasgupta, S., Rahman, M.: Towards transportation digital twin systems for traffic safety and mobility: A review. IEEE Internet of Things Journal (2024)
9. Koot, M., Mes, M.R., Iacob, M.E.: Building an ontological bridge between supply chain resilience and iot applications. In: International Conference on Enterprise Design, Operations, and Computing. pp. 79–96. Springer Nature Switzerland (October 2023)
10. Kritzinger, W., Karner, M., Traar, G., Henjes, J., Sihn, W.: Digital twin in manufacturing: A categorical literature review and classification. IFAC-PapersOnLine **51**(11), 1016–1022 (2018)
11. van Lamsweerde, A.: Goal-oriented requirements engineering: a guided tour. In: Proceedings Fifth IEEE International Symposium on Requirements Engineering. p. 249–262. ISRE-01, IEEE Comput. Soc (2002)
12. Liu, Y., Folz, P., Pan, S., Ramparany, F., Bolle, S., Ballot, E., Coupaye, T.: Digital twin-driven approach for smart city logistics: The case of freight parking management. In: Advances in Production Management Systems. Artificial Intelligence for Sustainable and Resilient Production Systems: IFIP WG 5.7 International Conference, APMS 2021. pp. 237–246. Springer International Publishing, Nantes, France (September 5–9 2021)
13. Liu, Y., Pan, S., Ballot, E.: Unveiling the potential of digital twins in logistics and supply chain management: Services, capabilities, and research opportunities. Digital Engineering **3**, 100025 (Dec 2024)
14. Notteboom, T.E.: Concentration and the formation of multi-port gateway regions in the european container port system: an update. Journal of Transport Geography **18**(4), 567–583 (2010), special Issue on Comparative North American and European gateway logistics
15. Park, J., Seager, T.P., Rao, P.S.C., Convertino, M., Linkov, I.: Integrating risk and resilience approaches to catastrophe management in engineering systems. Risk Analysis **33**(3), 356–367 (Sep 2012)
16. Ponsard, C., Massonet, P., Molderez, J.F., Rifaut, A., Lamsweerde, A.v., Van, H.T.: Early verification and validation of mission critical systems. Formal Methods in System Design **30**(3), 233–247 (Dec 2006)
17. Roman, E.A., Stere, A.S., Roșca, E., Radu, A.V., Codroiu, D., Anamaria, I.: State of the art of digital twins in improving supply chain resilience. Logistics **9**(1), 22 (Feb 2025)
18. Saroj, A.J., Roy, S., Guin, A., Hunter, M.: Development of a connected corridor real-time data-driven traffic digital twin simulation model. Journal of Transportation Engineering, Part A: Systems **147**(12), 04021096 (2021). https://doi.org/10.1061/JTEPBS.0000589
19. SteadieSeifi, M., Dellaert, N., Nuijten, W., Van Woensel, T., Raoufi, R.: Multimodal freight transportation planning: A literature review. European Journal of Operational Research **233**(1), 1–15 (Feb 2014)
20. Upadhyay, P.: The role of verification and validation in system development life cycle. IOSR Journal of Computer Engineering **5**(1), 17–20 (2012)
21. Wojciechowski, P.: Fifth work plan of the european coordinator (2022), https://transport.ec.europa.eu/system/files/2022-10/5th_workplan_ralp.pdf