Proceedings of the 2025 Winter Simulation Conference
E. Azar, A. Djanatliev, A. Harper, C. Kogler, V. Ramamohan, A. Anagnostou, and S. J. E. Taylor, eds.

DEVELOPMENT OF A LIBRARY OF MODULAR COMPONENTS TO ACCELERATE MATERIAL FLOW SIMULATION IN THE AVIATION INDUSTRY

Hauke Stolz[1], Philipp Braun[1], Hendrik Rose[1], Helge Fromm[2], and Sascha Stebner[2]

[1]Institute of Logistics Eng., Hamburg University of Technology, Hamburg, GERMANY
[2]Airbus Operations GmbH, Hamburg, GERMANY

ABSTRACT

Aircraft manufacturing presents significant challenges for logistics departments due to the complexity of processes and technology, as well as the high variety of parts that must be handled. To support the development and optimization of these complex logistics processes in the aviation industry, simulation is commonly employed. However, existing simulation models are typically tailored to specific use cases. Reusing or adapting these models for other aircraft-specific applications often requires substantial implementation and validation efforts. As a result, there is a need for flexible and easily adaptable simulation models. This work aims to address this challenge by developing a modular library for logistics processes in aircraft manufacturing. The outcome of this work highlights the simplifications introduced by the developed library and its application in a real aviation warehouse.

1 INTRODUCTION

Manufacturing airplanes requires a large number of different parts in a wide range of sizes, including small rivets, lavatories, and large wings. Additionally, these parts originate from various suppliers, and most are dedicated to a specific aircraft. This variety of components and the high number of suppliers pose significant challenges to internal logistics and result in complex processes needed to supply the correct part to the right point of use.

Logistics processes in the aviation industry are often performed manually due to the highly specific geometries of materials and load carriers. Furthermore, processes in the aviation industry must be certified by authorities such as the Federal Aviation Office in Germany (Federal Aviation Office 2025). Due to the still high degree of manual effort and the special geometries of the materials, there is a growing interest in implementing automated solutions in aviation manufacturing and logistics. Thus, there is considerable potential to improve logistics processes by increasing the degree of automation within the aviation industry.

For decades, simulation has been used as a tool to improve and validate planning during the development of new production facilities. In 2008, a VDI guideline for the development of the "digital factory" was introduced (Verein Deutscher Ingenieure 2008). This guideline includes simulation as a method for designing or verifying planned processes. With ongoing advancements in information technology, the demand for simulation models continues to rise (Sokoll et al. 2021). Therefore, simulation represents a valuable tool for testing and optimizing new processes and innovative logistics solutions.

To make the simulation of logistics processes in the aviation industry more flexible and to reduce modeling effort, this work implements a simulation library for an aviation manufacturer. The use of a simulation library offers a means of reducing the effort required to model complex processes by providing predefined, reusable modules (Jeong 2023).

To analyse the possibility of implementing a modular and reconfigurable simulation library which can reduce simulation effort significantly, following research questions are posed:

979-8-3315-8726-0/25/$31.00 ©2025 IEEE

- "How can a modular library for the simulation of processes in warehouses in the aviation industry be designed to enable less demanding simulation modeling?"
- "To what extent can existing processes in the aviation industry be generalized so that they can be transferred to the library?"
- "Which simplifications for the creation of simulation models can be achieved by applying the library while maintaining comparable simulation accuracy?"

These research questions address the potential design of a simulation library and its implications for the modeling process. As a result, this paper presents a library containing several modules for simulating material flow within storage facilities in the aviation industry.

2 LITERATURE REVIEW

In the aviation industry, simulation is applied across various fields, covering different aspects of the aircraft lifecycle. Oesingmann et al. (2024) simulated the future energy demand of airplanes by considering alternative fuels such as hydrogen and sustainable aviation fuel. One study modeled the production process of sustainable aviation fuel using simulation methods (Elkelawy et al. 2022). Simulation is also used in the planning of prescriptive maintenance for aircraft, for example through the application of discrete-event simulation (Meissner et al. 2021). Another study by Korchagin et al. (2022) highlights the potential of implementing Industry 4.0 technologies in aircraft maintenance. The data collected through these technologies can be integrated into simulation models to enhance and optimize maintenance processes. (Goedecke et al. 2023) initiated the definition of requirements for a logistic simulation library tailored to the aviation industry.

Zhang et al. (2020) simulated the coupling effects of fatigue damage and tooth wear on landing gears using a finite element method (FEM). The studies presented demonstrate that simulation is applied in various fields within the aviation industry, including the production of alternative fuels and the planning of aircraft maintenance. However, simulation studies focusing specifically on the manufacturing process and its associated logistics remain limited. Simulations of logistics processes tailored to the aviation manufacturing industry are particularly scarce. This work aims to enhance the applicability of simulation in this area by providing a more accessible and structured approach to modeling logistics processes in the aviation sector.

In addition to the need for material flow simulations in the field of aircraft manufacturing, researchers are increasingly focusing on improving the efficiency of model implementation by seeking to reduce the associated effort. The reduction of modeling effort can be achieved through various methods, depending on the chosen approach. Current strategies for minimizing modeling effort can generally be categorized into model-based and data-based approaches (Schlecht et al. 2023). These two approaches differ primarily in their degree of abstraction. The model-based approach simplifies system modeling by utilizing reusable components, whereas the data-based approach relies on a defined data structure as input, from which a model is automatically generated (Schlecht et al. 2023).

The choice of approach depends on the system's complexity, as there is a correlation between complexity and generality of simulation models (see Figure 1). As generality increases, complexity decreases, and as complexity increases, generality decreases (Schlecht et al. 2023).

As an example for a data-based approach Wang et al. (2011) developed a method to automatically generate a model from various input data, using a case study from the automotive sector. The input data included a database with substantial process data such as buffer capacities, processing times, and the bill of materials for each product. In recent works, the source of data has shifted, with logs from production planning software being utilized.

Lugaresi and Matta (2023) also explored automated model generation. In this work, the material flow was converted into a graph from which a model can be derived. To apply the data-based approach, a domain-specific description of the system is required. This could, for example, be in the form of a simulation

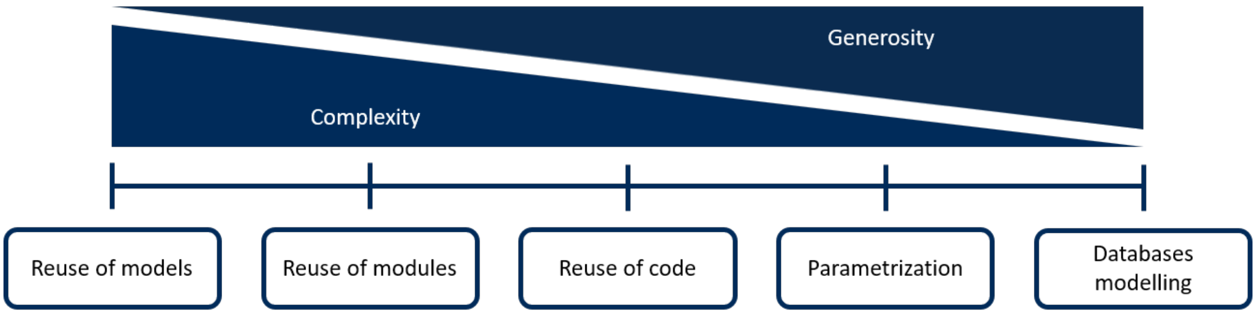

Figure 1: Relationship between complexity and generosity (Based on: Schlecht et al. (2023)).

library. In conclusion, the data-based approach is more generic but struggles to model complex systems. In contrast, the model-based approach is often preferred for more complex use cases.

For the aviation industry, a model-based approach in the form of a library is chosen in this work, as the processes in the aviation sector are highly complex, involving a large number of different components and handling methods.

The current state of the literature indicates that there is limited existing research on simulation libraries, despite the fact that initial concepts were developed as early as 2008 (Soyka and Steinhauer 2088).

As part of the work by Sokoll et al. (2021), a block library was developed to support simulation activities, with a particular focus on logistics operations within the automotive industry. This library is structured into two main groups, each serving a distinct function within the simulation framework. The first group consists of structural elements that define the physical layout of the system, including components such as road networks and designated parking areas for vehicles. The second group comprises process modules, which represent the sequence of transport and work steps involved in operational procedures. These two core groups are further complemented by prefabricated statistical modules, which support the integration of data-driven elements into the simulation. Findings from the study suggest that the development of an internal, company-specific simulation library can contribute to shorter development times and, as a result, reduce the overall development effort required (Sokoll et al. 2021). However, this library cannot be directly applied to the aviation industry, as many processes in that sector are still performed manually due to specific operational requirements and lower throughput compared to the automotive domain. Furthermore, the processes in the aviation industry are generally carried out with a lower degree of automation, which limits the direct transferability of simulation tools developed for more automated environments.

As part of the work conducted by Aretoulaki et al. (2024), existing literature on the application of discrete-event simulation and digital twins in the warehouse sector was analyzed. It was observed that many publications focus on individual use cases and specific problems, without addressing broader applicability. To improve the flexibility of simulation models, it is necessary to implement more adaptable simulation approaches, such as the use of simulation libraries. The application of generic models and universal structures is important in order to enable the transformation of a discrete-event simulation into a digital shadow. In this context, a library forms the foundation for creating a digital shadow, as it provides a structured description of the applied domain.

This literature review revealed several research gaps that this paper aims to address, as listed below:

- Simulation models are rarely reusable because they are often developed for specific problems.
- Few works focus on the development of simulation libraries.
- A focus on the manufacturing and the logistic processes of airplanes is missing in the literature.

In summary, simulation models in the aviation industry cover areas such as the development of sustainable fuels and predictive manufacturing, and are generally related to specific use cases. In order to make simulation more adaptable and flexible, either a model-based or data-based approach can be selected. A model-based approach is particularly suitable for the aviation industry due to the complexity of its processes. This work aims to extend the range of applications by developing a library for logistics simulation in aviation industry.

This work seeks to address these gaps by developing generalized and multifunctional modules that serve as a foundation for potential future automated model generation. Therefore, the focus of this work is on the aviation industry, which is characterised by complex and certified processes, as well as the production of small lot sizes.

3 DEVELOPMENT OF THE LIBRARY

To simplify the development effort for material flow simulation modeling in aircraft manufacturing logistics, a modular library for reconfigurable modules is developed. The development is divided into four steps. First, the requirements for the library are identified. From the requirements the concept of the library is derived. In the following step the process modules with the resources are developed. To validate the feasibility of the library, it is applied in a use case simulating an aircraft manufacturing warehouse area.

3.1 Requirements of the Library

The information for conducting the requirements analysis was gathered through a workshop with logistics and simulation experts from an aviation manufacturer. The participants worked in groups to define their considerations regarding constraints, input factors, output factors, and potential application areas for the library. The results were then derived and categorized into four key areas: software development, use of generalized components, use of standardized key performance indicators (KPIs), and documentation. All of these areas are addressed in the development of the library. The outcome is illustrated in Figure 2.

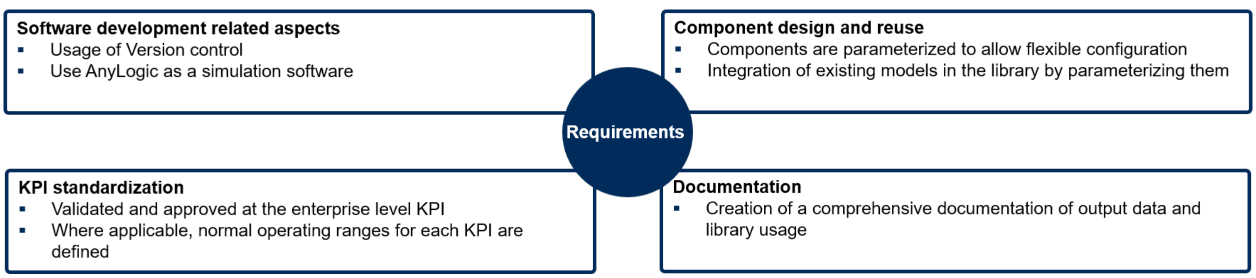

Figure 2: Requirements for the library.

The category of software development includes the requirements related to the applied software environments. First, version control should be implemented to track milestones and enable collaborative development of the library within a team. Second, the library should be developed using the simulation software AnyLogic, which is the standard tool employed by the aviation manufacturer.

The second category addresses the methodological approach for designing the components within the library. These components should be parameterized to allow for flexible dimensioning. The aircraft manufacturer has already developed simulation models for specific use cases. These existing models will be integrated by extracting various modules, which can then be reused in different use cases. The extracted components from the existing models will also be parameterized to enhance flexibility.

The next category concerns KPIs. The output should align with the KPIs used by the manufacturer, such as storage throughput or CO_2 emissions. The results are to be displayed on a standardized visual output dashboard. If possible, an acceptance range for the KPIs should be provided to facilitate initial validation, ensuring that all KPIs fall within the normal range.

The final category is documentation. To ensure ease of use, all components of the library will be described in detail in the documentation.

3.2 Library Concept

The library concept is structured around three major components: the architecture concept, the modeling concept, and the validation concept. The following section describes the architecture concept. AnyLogic is used for the implementation of the library (see Section 3.1). It is particularly well suited for simulating specific processes in the aviation industry, as the software enables flexible implementation of individual components. In contrast, tools specialized in logistics simulation often have limitations, especially when it comes to modeling potential picking strategies. Additionally, the use of AnyLogic represented a constraint for the aircraft manufacturer.

The architecture concept outlines the general structure of the library (see Figure 3). The development steps for the components are saved by the developers in a repository to ensure that a backup is always available during the development process.

In AnyLogic, the model structure divides developed components into agents, which represent the resources used, and flowchart blocks, which represent the processes. These components are stored in separate libraries. However, there is a dependency between the agents and the flowchart blocks, as the functionality of the flowchart blocks depends on the presence of the agents. Once a block is completed, it is documented. This documentation is also stored in the repository and serves as a guide for users (simulation developers) when utilizing the blocks. Completed blocks are compiled into a *.jar* file and stored in the application library. Users can download the *.jar* files from the application library and import them into their individual simulation models.

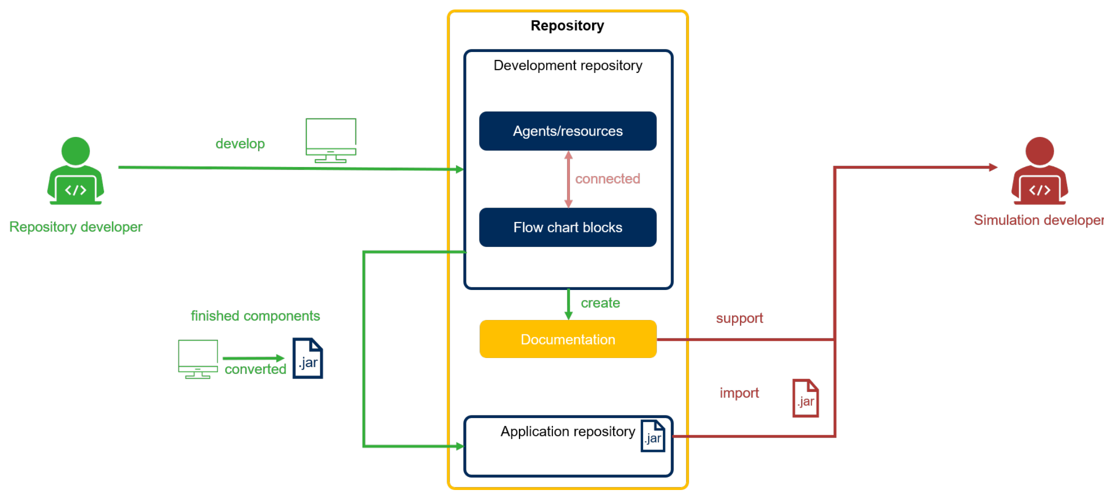

Figure 3: Architecture concept.

The library developed in this work consists of four distinct sub-libraries. One sub-library focuses on process modules, while the remaining three are organized thematically to handle agents and resources. The first agent library is dedicated to movable resources, containing agents capable of transporting units such as pallets or boxes. The second, known as the picking library, includes agents used in the picking process, such as a picklist agent. The third library contains the transport unit agents themselves, such as pallets or boxes, which represent the physical items being moved.

3.3 Development of Process-blocks

This library is based on a general material flow within an aviation manufacturer, covering the processes from delivery to goods receipt, storage, picking, and outbound processing within a warehouse in the aviation industry. The general material flow is illustrated in Figure 4.

The first step involves delivery by truck (truck arrival). The system then checks whether customs clearance is required. If customs clearance is necessary, the customs process is performed; otherwise, the next process step is initiated. In the following step, the arrival of the items is recorded, and any deviations or quality issues are checked. If any discrepancies (e.g., quantity, type, etc.) are detected, the corresponding corrective dispute process is triggered and applied. After the check and any associated processes, the items are stored until they are called for. Once storage is complete, the picking and outbound processes begin.

Figure 4: General materialflow.

Specifically, this leads to the flowchart blocks for the library, as shown in Figure 5. Each process step from the process outlined in the previous paragraph corresponds to a single module. However, the goods receipt, storage, and picking processes require multiple versions of these blocks, which is why these steps contain several flowchart blocks.

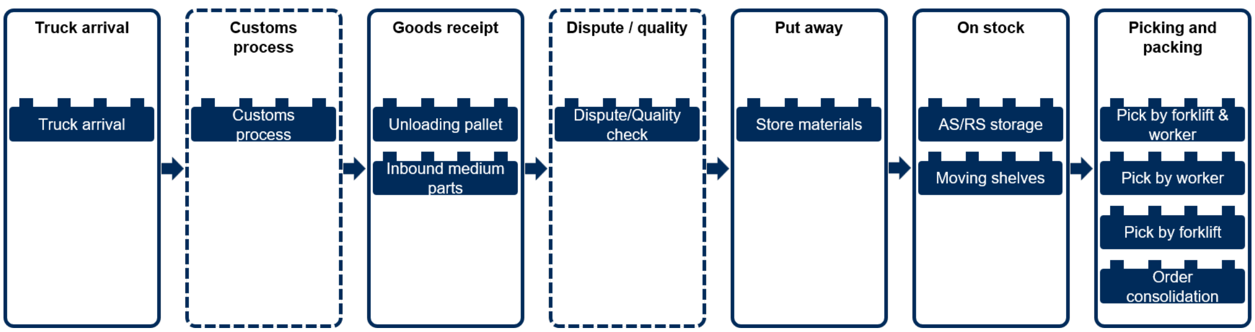

Figure 5: Overview of the processblocks inside the library.

3.4 Application in an Industrial Use Case

To test the library, a real use case was selected. In this use case, a comparative study between manual picking storage and automated storage (ASRS) is conducted, with a focus on evaluating the library. To derive recommendations on which system to select, additional experiments need to be conducted. The procedure followed aligns with the simulation study procedure outlined in the VDI guideline 3633 (Verein Deutscher Ingenieure 2014). The evaluation of the use case is based on the parameter of outbound throughput to provide insights into the system selection.

The simulation model consists of three main components: the layout, the resources, and the flowchart (Figure 7). The layout defines the orientation and location of storage areas and pathways within the warehouse, as well as the dimensions of distances and areas.

The second component of the simulation model is the resources, focusing on the storage technologies and the moving resources employed. In this use case, two storage technologies are used, depending on the experiment. The first technology, shelving racks, is designed for manual picking, while the second technology is an automated storage system. The shuttle system was chosen as an automated storage technology in coordination with the aircraft manufacturer, as the technology is already in use at further warehouses of the aircraft manufacturer. For this study, a generic model of a shuttle system was selected.

For moving resources, personnel and forklifts are utilized. Personnel perform tasks such as unpacking, storing the materials into the storage, and picking processes, while forklifts are responsible for transporting delivered pallets to the unpacking station.

The most critical component of the simulation model is the flowchart, where the activities of the resources and the material flow processes are defined. Whenever possible, flowchart blocks from the library are used. These blocks are identified by three white arrows on a dark blue background. From the start to the end of the process, blocks from the library are incorporated.

The validation of this model is performed by comparing the results from the simulation model with existing performance data, including delivery, initial stock, and picking parameters of the aviation warehouse, with a focus on outbound parameters. The duration of the existing data is two days, which also serves as the simulation time and contains the actual performance of the real warehouse for this period. The comparison is made with respect to the storage outbound process, and the parameters for validation are the number of processed order lines and throughput.

Figure 6 presents a comparison of the progression between the simulation run and the provided data. This plot shows that the progressions are very close to each other, although there is a larger difference in performance at the beginning, measured by throughput. One possible reason for this difference could be the strategy used to process the picklists. At the start of the simulation, the distances to the storage locations of materials are greater, whereas in the latter part of the simulation, the distances decrease. In the simulation model, the picklists were processed in a random order after being released.

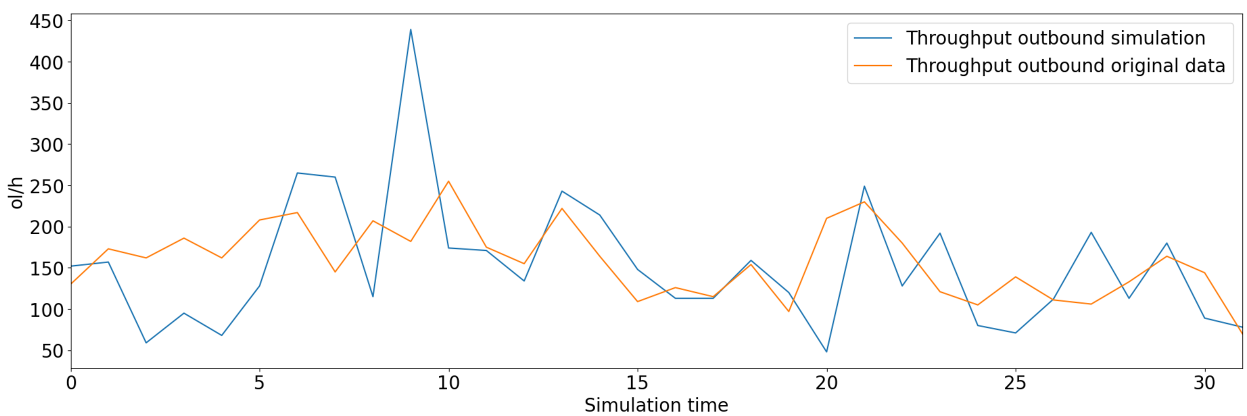

Figure 6: Comparison of the throughput between the simulation and the offered, real data.

After the validation is completed, experiments can be conducted. The parameters for the experiments are outlined in Table 1. The experiments are performed with 20 replications. While more replications would provide more precise results, this number has proven to be sufficient for the use case, as it effectively covers specific constellations caused by random variables. Additionally, this number of replications ensures a reliable result for the evaluation of the library.

4 RESULTS

This section is divided into two parts. The first part focuses on the validation of the implemented modules within the library. The second part describes the results derived from the application of the library.

4.1 Validation

The development of a block library is only worthwhile if similar simulation results can be achieved with simplified creation of simulation models as with individually developed simulation models. To ensure this, the simulation modules developed as part of this work are validated.

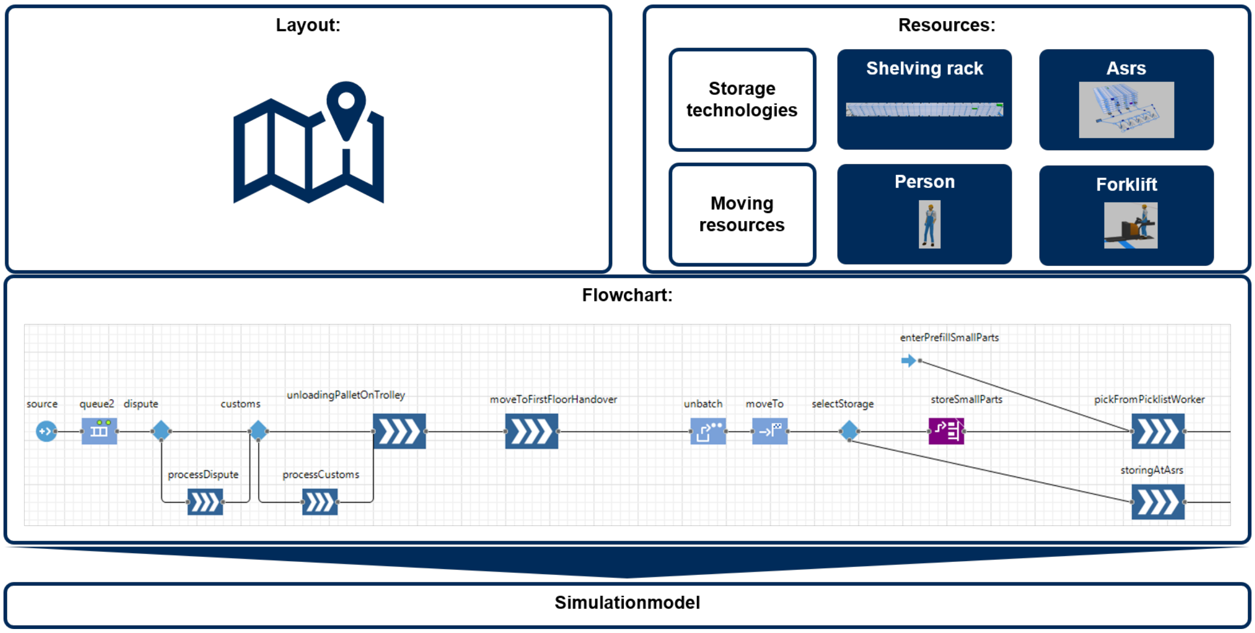

Figure 7: Composition of the simulation model.

Table 1: Parameters for the experiments.

Experiment parameter	Value
2 Shiftmodel (06:00 - 14:00 & 14:00 - 22:00)	
Working hours per shift	8 hours
Duration of simulation	2 days
Number of orderlines	5010 orderlines
Transfertime to first floor	40s
Speed of persons	4 km/h
Speed of forklifts forklift	8 km/h
Number of replications	20 replications

For this purpose, processes from a use case are compared with the functions from existing simulation models as well as the prefabricated modules (Table 2). The comparison is carried out using individually selected validation parameters for each module. A module is only considered valid if the parameters of both models match by 95 percent. This validation approach is applied only when a comparable model already exists. Other modules are validated using visual and logical checks. Visual and logical checks are methods of validation according to the VDI guideline 3633 (Verein Deutscher Ingenieure 2014). In particular, the visual checks are performed by observing the rendered 3D model and carefully monitoring the behavior of the resources to identify any unexpected behavior. Additionally, expected parameters that can be calculated, such as process times, are selected for visual checks.

4.2 Application of the Library

The developed library is applied to a use case to test its functionality and evaluate its usability in an industrial environment. An anonymized warehouse of an aviation manufacturer is selected for this application.

First, the result of this work is a library containing flowchart blocks and resources for modeling a complete warehouse process in the aviation industry. The requirements identified at the beginning of this work have been fulfilled. The library was implemented in AnyLogic and incorporates version control.

Table 2: Each module was validated separately with different parameters. The column validation type shows how the blocks were validated. Some blocks were validated with compare the block to an existing model (Com). If no comparable model exist the modules were validated by a technical and visual inspection (Tech).

Module	Validation parameters	Validation type	Validation result
Picking by person and forklift	Number of processed orderlines	Com	95%
Unloading pallet (2 blocks)	Number of processed pallets	Com	100%
Optional, additional tasks	Worker utilization; Traveled distances	Com	100%
Pick by person	Number of processed orderlines; process time per picklist	Com	96%
Transport by resource	Number of transported materials	Tech	100%
Source for materials	Number of created agents	Tech	100%
Automated storing and retrieval system	Moving times; Transport times on conveyor belt	Tech	98%

All components, including flowchart blocks and resources, are parameterized, and, where possible, the flowchart blocks and resources were designed based on existing models. This meets the second category of the requirements.

The output of the flowchart blocks and resources has been coordinated with the aviation company, and the use case demonstrated that the three sustainability categories can be effectively addressed. Last but not least, the library is fully documented and can be used by users as a guide.

The parameterization allows for the scaling of components. One example is the automated storage, which is generated at the beginning of the simulation based on the specified parameters. One of the parameters is the dimension of the storage. These dimensions can be easily adjusted to meet the individual needs of the users, as a pre-configured input field is available for this resource.

Quantifying the extent of simplification achieved with this block library is challenging. First, the number of flowchart blocks required for each individual process block is analyzed. Table 3 shows the number of AnyLogic flowchart blocks for each process block. This table reveals that each process block consists of at least two flowchart blocks, with the average number being 12.6, which is significantly higher than the minimum. This suggests that each process block combines specific sequences of flowchart blocks into a cohesive process step.

The *Picking by person and forklift* block contains the most flowchart blocks, with a total of 34 blocks. In addition to this high number of blocks, a complex control system for the picking process is also implemented within this block. As a result, the entire picking process does not need to be re-implemented when using the library, as it is already encapsulated within this process block. This significantly reduces the effort required to model an order picking process. A similar benefit applies to the *Picking by person* block, which consists of only 11 flowchart blocks but still incorporates the necessary logic to control the picking process.

Another feature that enhances customization is the flexibility to arrange the developed process blocks in any desired order, as long as the output from one block is compatible with the input type of the subsequent block. If this condition is not met, the simulation model cannot be run, signaling that the logic of the modeled process may need to be revised. This flexibility allows for the modeling of alternative sequences of process steps, different from those in the case study, while still using the block library.

Table 3: Number of flowchartblocks inside the library blocks.

Name of the flowchart block	Number of blocks inside the block
Picking by person and forklift	34
Unloading pallet (2 blocks)	18
Optional, additional tasks	8
Pick by person	11
Transport by resource	3
Source for materials	2

5 DISCUSSION

The application of the library in a real-world aviation warehouse reveals various quantitative and qualitative aspects regarding simplifications and reusability. Using the library reduces the modeling effort at different levels, depending on the specific use case.

Overall, the analysis based on comparative models and the general material flow of an aviation warehouse led to a concept that demonstrates how processes are represented within a flowchart block. This concept, grounded in the general material flow, helps modelers navigate the library, allowing them to easily derive the appropriate flowchart block from the well-known general aviation warehouse material flow.

The concept developed in this work addresses the complexity of modeling logistic processes in aviation industry by striking a balance between reducing modeling effort and maintaining a high degree of reusability. Modeling such processes is challenging due to the wide range of possible configurations and operational variations. This work mitigates that complexity by implementing the general material flow as a series of modular steps that only require parameterization. Furthermore, the clear separation between individual process steps supports flexibility in application and enables a high level of reusability. The developed library can be applied to processes in external warehouses, provided the operational steps correspond to those represented in the library. The library has limitations when it comes to processes that deviate from those represented by its components. If a different warehouse operates with significantly different process steps, the library cannot be applied without major modifications. Furthermore, the developed library is tailored specifically to the aviation industry. As a result, its applicability to other industries may be limited due to differences in process structure, standards, or operational requirements. Although the library contains pre-validated components, each simulation study utilizing the library must undergo validation. Skipping this step may lead to modeling errors in the simulation study.

Using the library can significantly impact the modeling process. However, it is important to recognize that these influences will vary depending on the specific case study. The impact is likely to be greater for models simulating processes that closely resemble those for which the library was originally developed. For example, the selected warehouse in this study served as a template for modeling detailed processes. As a result, optimal outcomes with the library are most likely to be achieved when the processes being modeled closely align with those of the warehouse used in this work. Therefore, the use of the library is best suited for such scenarios.

A positive aspect of the library is that the pre-developed modules with built-in logic significantly accelerate the modeling process by reducing the need for reimplementation. Additionally, the linear and continuous flowchart structure enhances the clarity and comprehensibility of the model. In the use case (see Section 4.2), most of the modeled processes used flowchart blocks and resources from the library. This demonstrates that the library not only enables the fast creation of short simulation models but also makes the flowcharts much clearer. Furthermore, the validation of each component provides confidence that the library can be used to generate models that closely resemble the real system to a certain extent.

In summary, this work establishes a foundation for simplifying the simulation of complex logistical processes in the aviation industry through the use of modularization. Furthermore, it provides a basis for the potential automation of system modeling by utilizing prefabricated modules. In Section 3, a simulation library was designed and implemented based on the specific requirements of an aviation manufacturer, addressing the first research question. To answer the second research question, the modules within the library were derived from a general material flow typical of the aviation industry, whereby each step in the material flow corresponds to a specific module within the library.

One of the key outcomes of this work is a completed library containing modules that represent complex processes within an aviation warehouse. When applied to real use cases, as demonstrated in this study, these modules can be reused by simply parameterizing them according to the specific context. This approach significantly reduces modeling effort and highlights the library's impact on the overall modeling process, thereby addressing the third research question.

6 CONCLUSION

The aviation industry poses significant challenges to logistics departments due to the variety of materials that need to be handled in small quantities. To manage these materials effectively, a precise logistics concept is necessary. Simulation is used to support the development of new concepts and the improvement of existing ones. This work presents an approach to reduce the simulation effort for logistics processes in the aviation industry and demonstrates what a modular library can look like. It also compares this approach to existing, application-specific simulation models.

The developed modular library simplifies the creation of simulation models for logistical processes in an aviation warehouse by providing predefined modules for complex processes. This was achieved through an analysis of material flows in several air freight warehouses and by developing reusable modules based on these flows. The material flows are based on a general warehouse process commonly used in the aviation industry. To maximize reusability, the modules are parameterized, allowing for easy customization with minimal programming effort. This can reduce future modeling efforts and potentially shorten the time required to develop future simulation models.

At this stage, the fields of application of the library remain limited. The storage technologies currently included in the library are restricted to shelving racks, automated storage systems, and pallet racks. Additional technologies will need to be implemented in future work to broaden the scope of application. Furthermore, the library was tested in a single use case. In order to gain a more comprehensive understanding of its fields of application, the library should be applied to additional use cases in future studies.

This work offers initial insights that can support the development and possible future automation of simulation models in the aviation industry. Future work could focus on developing an algorithm that utilizes a defined format of existing input data and the modules from this library to create a simulation model.

In addition to the automated creation of simulation models, this library can be used to conduct sustainability assessments as part of further work on warehouse logistics systems within aviation industry. In summary, this work not only contributes to a modular structure for accelerating the creation of simulation models in the warehouse logistics context of aviation processes, but it also forms the basis for future automated simulation model generation.

REFERENCES

Aretoulaki, E., S. T. Ponis, G. Plakas, and D. Tzanetou. 2024. "(DT4Smart) Discrete Event Simulation and Digital Twins in Warehouse Logistics: A Bibliometric and Content Analysis-based Systematic Literature Review". *International Journal of Computer Integrated Manufacturing* 37(10–11):1376–1403.

Elkelawy, M., H. A. Bastawissi, A. M. Radwan, M. T. Ismail, and M.. 2022. "Biojet Fuels Production from Algae: Conversion Technologies, Characteristics, Performance, and Process Simulation". In *Handbook of Algal Biofuels*, 331–361. Elsevier.

Federal Aviation Office 2025. "Luftfahrt Bundesamt - Division Airworthiness/Environmental Protection - Tasks and Information within Unit Production Organisations". https://www.lba.de/EN/LBA/Organisation/Abteilung_T/T1/T11/T11_Information.html?nn=622568. Accessed: 17th March 2025.

Goedecke, B., H. Fromm, K. Fischer, and P. Braun. 2023. "A Logistics Simulation Model Repository to Accelerate Simulation Modeling in the Aerospace Industry". In *2023 Winter Simulation Conference (WSC)*.

Jeong, Y. 2023. "Digitalization in Production Logistics: How AI, Digital Twins, and Simulation are Driving the Shift from Model-based to Data-driven Approaches". *International Journal of Precision Engineering and Manufacturing-Smart Technology* 1(2):187–200.

Korchagin, A., Y. Deniskin, I. Pocebneva, and O. Vasilyeva. 2022. "Lean Maintenance 4.0: Implementation for Aviation Industry". *Transportation Research Procedia* 63:1521–1533.

Lugaresi, G., and A. Matta. 2023. "Automated Digital Twin Generation of Manufacturing Systems with Complex Material Flows: Graph Model Completion". *Computers in Industry* 151:103977.

Meissner, R., A. Rahn, and K. Wicke. 2021. "Developing Prescriptive Maintenance Strategies in the Aviation Industry Based on a Discrete-Event Simulation Framework for Post-Prognostics Decision Making". *Reliability Engineering System Safety* 214:107812.

Oesingmann, K., W. Grimme, and J. Scheelhaase. 2024. "Hydrogen in Aviation: A Simulation of Demand, Price Dynamics, and CO2 Emission Reduction Potentials". *International Journal of Hydrogen Energy* 64:633–642.

Schlecht, M., R. Guio, and J. Köbler. 2023. "Automated Generation of Simulation Model in Context of Industry 4.0". *International Journal of Modelling and Simulation* 45(2):441–453.

Sokoll, K., P. Braunschweig, L. Gustafsson-Ende, and F. Hilmer. 2021. "Ein Unternehmensübergreifender Standard für Logistiksimulation mit Grafischer Prozessmodellierung". In *Simulation in Produktion und Logistik 2021, 19. Fachtagung*. September 15th-17th, Erlangen, Germany, 505-514.

Soyka, M., and D. Steinhauer. 2088. "Simulation Logistischer Abläufe an Bord von Schiffen". In *13. ASIM Fachtagung Simulation in Produktion und Logistik*. October 1th-2th, Berlin, Germany, 91–100.

Verein Deutscher Ingenieure 2008. *VDI-Guideline 4499 Part 1 Digital Factory Fundamentals*. Verein Deutscher Ingenieure. ICS 03.100.50.

Verein Deutscher Ingenieure 2014. *VDI-Guideline 3633 Simulation of systems in Materials Handling, Logistics and Production*. Verein Deutscher Ingenieure. ICS 03.100.10.

Wang, J., Q. Chang, G. Xiao, N. Wang, and S. Li. 2011. "Data Driven Production Modeling and Simulation of Complex Automobile General Assembly Plant". *Computers in Industry* 62(7):765–775.

Zhang, B., H. Liu, C. Zhu, and Y. Ge. 2020. "Simulation of the Fatigue-Wear Coupling Mechanism of an Aviation Gear". *Friction* 9(6):1616–1634.

AUTHOR BIOGRAPHIES

HAUKE STOLZ is a research agent at the institute of logistics engineering at Technical University of Hamburg (TUHH). He finished his M.Sc. in Logistics, Infrastructure and Mobility in 2025 at the TUHH. His research fields is materialflow simulation in any industry area. Moreover he is specialised in improving simulation methods. His email address is hauke.stolz@tuhh.de and his website is https://www3.tuhh.de/itl/hauke-stolz/.

PHILIPP BRAUN is chief engineer for simulation and planning of material handling systems at the Institute of Logistics Engineering at Hamburg University of Technology since 2023. After studying Logistics and Mobility and International Industrial Engineering, he has been working at the Institute of Logistics Engineering since 2019 in the field of material flow simulation, logistics planning, and material flow optimization. His email address is philipp.braun@tuhh.de.

HENDRIK ROSE is chief engineer for robotics and automation at the Institute of Logistics Engineering at Hamburg University of Technology since 2023. After studying General Engineering Science and International Industrial Engineering, he has been working at the Institute of Logistics Engineering since 2021 in the field of autonomous systems, automated transports, and material flow optimization. His email address is Hendrik.wilhelm.rose@tuhh.de.

HELGE FROMM is a Research Project Engineer at Airbus Innovation Works, the research organization of Airbus, in the area of Innovative Concepts and Scenarios for Services, Maintenance and Logistics. Helge holds a PhD in Engineering focusing on future maintenance technology assessment from the Technical University of Darmstadt (Germany) and graduated in Mechanical Engineering and Business Administration from Hamburg University of Technology (Germany). His email address is helge.fromm@airbus.com

SASCHA STEBNER is now working as a logistics and transportation system engineer for Airbus Operations GmbH. He was a company sponsored student for Airbus Operations Gmbh and graduated as B.Sc. in Industrial Engineering and Business Management at Nordakademie - University of Applied Sciences. Thereafter, he studied Business Psychology at Nordakademie - Graduate School and graduated as M.Sc. His email address is sascha.stebner@airbus.com.