DOI: 10.22032/dbt.57887

Simulation in Produktion und Logistik 2023
Bergmann, Feldkamp, Souren und Straßburger (Hrsg.)
Universitätsverlag Ilmenau, Ilmenau 2023
DOI (Tagungsband): 10.22032/dbt.57476

Consolidation for Clothing Logistics in the German Armed Forces: A Simulation Analysis

Simulationsstudie zu Konsolidierungsstrategien für das Bekleidungsmanagement der Bundeswehr

Heiderose Stein, Tobias Uhlig, Daniel Seufferth, Oliver Rose,
Universität der Bundeswehr, Neubiberg (Germany),
heiderose.stein@unibw.de, tobias.uhlig@unibw.de, daniel.seufferth@unibw.de, oliver.rose@unibw.de

Abstract: Having the right article in the right place at the right time is a logistical challenge – and can be vital. In this context, the Armed Forces of Germany (Bundeswehr) assess options to make the existing supply chain for protective attire more agile using online-shopping strategies. In this setting, the supply is internal to the organization: this allows for using of different consolidation strategies and applying customers' risk aversion strategies to the supplier in using preventive sending strategies. To explore different delivery strategies, a high-level simulation model is proposed. Results show that with the applied strategies, the delivery of fitting articles on time can be improved: preventive sending can help to have the right article in place at the time needed, and consolidation helps to reduce the number of packages sent.

1 Introduction

Soldiers' protection and readiness depend on their equipment and gear supply. Essentially, the Armed Forces of Germany need to guarantee timely delivery of fitting functional attire for their soldiers, which matches the respective area of operation. This entails an enormous logistical challenge. Therefore, they currently employ their own classical store system, where clients fetch their attire at given distribution centres. However, there is a growing interest in making this process more agile towards individual and urgent needs, inspired by e-commerce solutions. Thus, necessary items can be sourced anytime and delivered directly to the client. Not being bound to opening hours of shops comes at the price of not being able to fit the clothes – and therefore is a risk leading to a higher rate of wrong sized articles for a customer (see Zennaro et al. 2022; Abdulla et al. 2019). In this context, we aim to provide a high-level analysis to assess the impact of a new supply system for protective attire logistics and evaluate strategies to ensure a timely supply. To this end, discrete event models are used to simulate various scenarios for potential implementations. This enables decision-makers to take an informed decision on improving the respective systems.

In the following section, an introduction to the context of this paper is given: the opportunities and challenges of e-commerce options for (protective) clothes in general as well as the special conditions of our use case. Additionally, an overview of relevant literature and simulation studies is given, focusing on shipment consolidation strategies and their implementation for supply at reasonable efforts. In the third section, the used model and implemented strategies will be described. The fourth section states the simulation scenario and parameters. The results of the initial experiments will be described in Section Five. The paper concludes with possible areas of development based on the first experimental results.

2 Context

In General, there is a growing interest in online shopping and Internet sales have increased dramatically over the past decade (Zennaro et al. 2022; Pedrielli et al. 2016). This offers convenience to customers like 24/7 shopping, and therefore an immediate requisition to new demands. Especially the second aspect is relevant for functional clothes, like medical or military gear, as it is vital to have medics and soldiers well-equipped when needed.

This trend challenges logistics, mainly in the fields of last-mile delivery and returns management. The last mile of delivery and returns drives socioeconomic costs (Zennaro et al. 2022). Problems in the last mile, i.e., the final shipment to the customers, are due to dispersed individual items and locations of the customers (Macioszek 2018). Return management is another issue: the number of returns in e-commerce is growing compared to classical stores (Abdulla et al. 2019; Zennaro et al. 2022), given the differences in the real product compared to the customers' expectations. Especially the textile industry faces challenges and opportunities in this setting and therefore explores digitalization opportunities (see Nobile et al. 2021; Seewald et al. 2019): for example, mobile applications have been developed to predict fitting sizes and prevent returns, with a focus on the fashion sector. For protective clothes, sizing differs based on the desired function. Therefore, a specific app has been developed (Oehlschäger et al. 2022), which can help to predict the correct size but may not prevent all returns of non-fitting apparel.

The use case described is intraorganizational, as both supplier and customer are part of the same organization. Therefore, both customers' and suppliers' needs are in focus. Hence, strategy evaluation may consider customers' risk-mitigating strategies as well as suppliers' strategies. Additionally, several customers are located at known sites where a storage place is accessible for deliveries at any time. Compared to standard cases, this allows the usage of interesting strategies to counteract transportation costs and return management due to shipment consolidation. Shipment consolidation, i.e., collecting several items into a single shipment (Ranathunga et al. 2021), is one strategy to reduce efforts in the supply chain and may significantly reduce sustainability costs in transport (Alnahhal et al. 2021; Romero-Silva and Mujica Mota 2022). Based on classifications from different authors (Romero-Silva and Mujica Mota 2022; Wei et al. 2021; Alnahhal et al. 2021; Memon et al. 2021;

Kang et al. 2017) shipment consolidation strategies can be organized into the following categories:

- Temporal consolidation strategies, which consolidate shipments over a certain period.
- Spatial consolidation strategies, which consolidate shipments by region or point of delivery.
- Product-based consolidation strategies, which consolidate different products into one shipment, based on economical or quantity consolidation.
- Hybrid consolidation strategies, combining two or more of these consolidation strategies.

Given the specific characteristics of the use case, three different strategies are implemented and compared to applying no strategy: First, with clients located in one place and a shared delivery hub, a hybrid, spatial-temporal consolidation strategy is implemented. This is addressing the orders from people located in the same area within a given timeframe of one day. As the equipment is needed at a certain date, and the main aim is delivery in time, any delay needs to be avoided: for example, late deliveries or returns. Thus, the preventive shipment of additional items in advance is implemented. This draws on the idea of consolidating shipments as well as on risk-mitigation strategies observed in online shoppers: Abdulla et al. 2019 state that online shoppers mitigate their risks by adding additional items to their basket and returning those that don't fit later. Yet, they observe scant literature addressing this topic and thus suggest developing theories for return policy design. Based on these ideas, we implement two preventive shipment policies to avoid downtime due to returns.

3 Methodology

This section describes the methodology used for modelling the new conceptual logistics system for the clothing management of the Bundeswehr. First, an abstract model of the fundamental ordering process is given. Then, the strategies for the consolidation of shipments and preventive packaging are explained in detail. Lastly, the first high-level model used for simulation is explained.

3.1 Abstract Model of the Order Processing and Shipment

The ordering process is modelled on an abstract level to investigate the main effects without a need to consider all the details. It is illustrated in Figure 1. The process starts with an order. For this paper it is assumed that all ordered goods are available, however, the option to consider backorders is included. With all goods available the next step is to pack everything into a parcel. This is the most important step of the model, since the packing process can change the behaviour significantly depending on the employed strategy. Here, the different consolidation approaches get applied, which will be discussed in detail in the following sections. After packing, the parcel will be sent, which is reflected by a timespan for the sending process. Upon arrival, consolidated shipments are immediately separated into individual orders, and unpacked by the customer. Then, the fit of all items gets checked. If any item does not fit, a reorder will be issued, and the respective item(s) will be returned. In this model, a reorder will always result in sending the correct size.

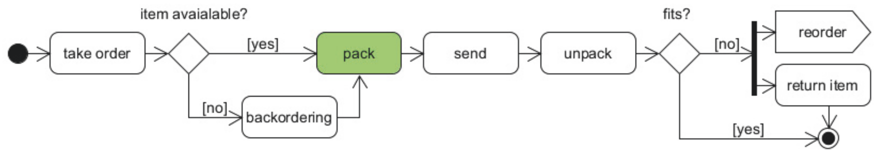

Figure 1: Scheme of order processing: The strategies become relevant in packing (marked green).

3.2 Implemented Strategies

In the following subsections, the implemented strategies will be discussed:

- A hybrid shipment consolidation strategy of items per individual and location hub and timeframe.
- Two preventive consolidation policies, to have everyone readily equipped at a given time using a shopping basket risk minimization approach.

These collections take place during packaging (see Figure 1 and Figure 2). Bundling orders for individuals, locations, and over a time frame allows for a more efficient shipment process, and preventive sending of additional articles allows for reducing delivery times for the right one, as stated in Section 2. As the focus is on fast delivery, shipping restrictions like packaging size, transportation mode and sustainability considerations are not yet included in this initial investigation.

3.2.1 Consolidation of Shipments per Location Hub

The use-case allows for employing shipment consolidation strategies based on the characteristics, that several people are located within one region and use a shared delivery hub. Additionally, orders are processed every day in the next warehouse and package restrictions are negligible, as there are several modes of transportation possible. These prerequisites would not all be viable for mail-order retailers or big e-commerce companies. To exploit the characteristics and assess their impact, the three following consolidation strategies are implemented in this first high-level model:

1. Temporal collection over a time window of one day.
2. Local collection within this timeframe per individual, i.e., one soldier.
3. Local collection of orders and returns within this timeframe and individuals in one location hub.

3.2.2 Preventively Consolidating Shipments with Additional Items

The main aim is to achieve on-time delivery of the right article. Adding additional items, when there is uncertainty that the right article is included, may help; this is the base of the preventive sending strategies, *PreSend* and *PreSendAbundant*. To this end, we want to minimize the number of deliveries that do not fit the customer, to avoid the need to resend other sizes of an item. To enable this, a predictor is needed that estimates a fit probability for a given size of clothing. This prediction can be based on historic data or body measurements. The Bundeswehr currently evaluates the use of a mobile app to measure the body of soldiers (Oehlschläger et al. 2022). Using this data, a digital twin with all relevant body measurements is generated for each soldier. With this prediction model, an estimate, of how likely a certain size of clothing will fit, can be calculated. The *PreSend* strategy simply adds an additional size for each item that exceeds a given threshold of fit uncertainty. The strategy operates under the assumption that the correct size is always between two sizes. Accordingly, if one size does not fit, the other size is the correct one. More complex scenarios with uncertainty between more than two sizes are ignored. As parcel size limitations are not relevant in this initial investigation, the *PreSend* strategy can easily be extended to the more generous concept *PreSendAbundant*. In this strategy when at least one item in an order has a fit uncertainty exceeding the threshold, two sizes for each item of the order are packed. Since already one additional item leads to a return parcel, ignoring packaging restraints and sustainability considerations more sizes can be included to further minimize the risk of one item not fitting.

3.3 Entities of the Model

Based on the abstract ordering process, the model visualized in Figure 1 is built as a discrete event model using the software *Anylogic*, employing the described strategies. The entities and parameters of the model are described in greater detail in the following subsections: items, orders, location hubs, and warehouses.

3.3.1 Item

The items represent the articles an individual soldier can order. It is characterized by three parameters: an ID, a name, and the fit probability of the item. The first two parameters are trivial and used to distinguish between different items. The fit probability implements the prediction probability of the app, introduced in (Oehlschläger et al. 2022), and gives the probability, of whether the correct size of the item is ordered or not. To represent one individual ordered item, with the measured and actual size of the article for that individual, a class *OrderItem* is used. The class provides functions and parameters that keep track of the measured size, the correct size, the fit probability, and if two sizes are shipped when using a preventive sending strategy. The measured size gets set during order creation and is based on the fit probability, meaning that an item with a fit probability of 60 % will be measured correctly 60 % of the time it gets ordered.

3.3.2 Order

The order represents what items one individual orders at that time and holds a list of all the items. The order follows the steps of the order process depicted in Figure 1, and it may be expanded by additional items in the pack-subprocess. For consolidating multiple orders into a shipment, a container *CollectiveOrder* is created, which is only used during sending.

3.3.3 Location Hub

The orders are created in the location hubs, as this is where the individuals reside. There are three different configurations of order creation, like basic swaps of old clothing, conversions to a different tactical uniform, or a complete initial order for one location hub. These three order creation methods differ in the number of orders they create and the interval they get executed. This leads to changing numbers of orders in the system and seasonal effects. The location hubs have different parameters needed for order creation to implement fluctuations in the number of items in one order.

Furthermore, every location hub has a given number of personnel that is used to determine the number of orders created for the three different order configurations.

Though in this first high-level model, only one location hub is implemented, the agent is tailored to easily be scalable, so a multitude of different sites with different geographical locations can be implemented in a more detailed model.

3.3.4 Warehouse

The warehouse is where the order processing visualized in Figure 1 takes place. Orders arrive from the location hub and follow the different process steps, depicted in Figure 1. The *pack* process is expanded with the two strategies for order consolidation and preventive sending. A detailed view of the *pack* process implemented is given in Figure 2.

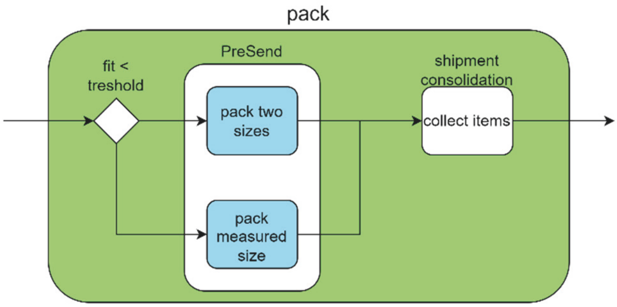

Figure 2: Packing process with implemented strategies for order consolidation and preventive sending.

4 Simulation Scenario and Parameters

This section describes the simulation scenario and the parameters used to explore the effect of the implemented strategies. To assess different settings, the performance metrics defined with the subject matter experts are described as well.

The scenario spans a year, where each individual soldier, orders several items stochastically over the year. Assumptions on the system are derived from discussions with experts and are exemplary: this includes the number of items ordered per individual, the item characteristics, the timeframe for collection, and the realistic delivery time of an order.

The goal of the simulation experiment is to get an understanding of the system and the different pack strategies, to assess the following:

- capacities needed for changing the system, i.e., the number of items and shipments that need to be sent based on the assumptions, and how different strategies impact them.
- delivery times needed for having the right item in place, and how different strategies impact them.

As a base reference, the number of items to ship without any consolidation strategy within any experiment is used. Parameters to change are the number of persons per location hub as well as forecasting probabilities for the item fit, based on the app or historical data, to understand how to use them to relieve the system.

5 Results

To evaluate the different strategies, the performance of the system regarding our aim is assessed. Different evaluation criteria for measuring performance are stated in the literature (see Alnahhal et al. 2021; Ma et al. 2020; Pedrielli et al. 2016; Kang et al. 2017). To evaluate the delivery times needed, lead times from order to delivery are calculated per simulation run.

To evaluate the capacity of the system, the number of sent items (separated into delivery and return), the number of sent shipments (where shipments can contain several items), and the mean number of items per shipment are calculated per simulation run. The number of sent items is used as a reference for each scenario, as this indicates the maximum number of shipments if no consolidation strategy is applied.

Results on artificial scenarios indicate that the strategies are successful: First, the number of shipments can be decreased, using shipment consolidation as illustrated in Figure 3. With more persons at one location, the number of items rises linearly, whereas the number of shipments is limited to one per day – as shipment sizes are unlimited in the initial model. This leads to shipments including growing numbers of items with more persons in one location hub.

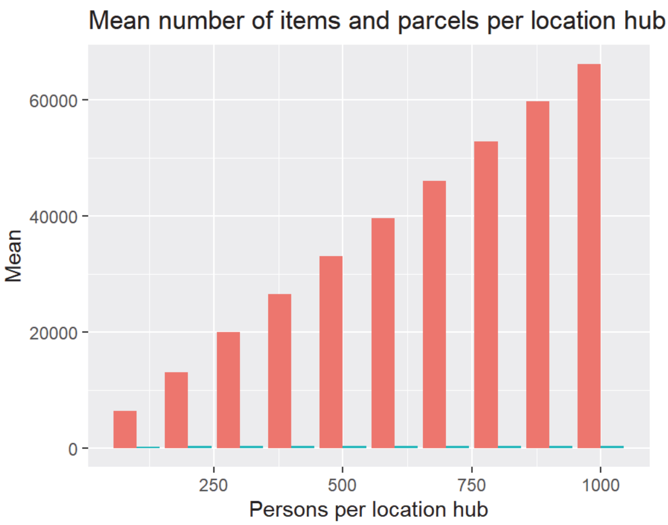

Figure 3: The mean number of items (coral) and parcels (turquoise) sent within 10 simulation runs are visualized.

Second, the waiting time for the right item can decrease using a preventive sending strategy, as visualized in Figure 4. Here, the following scenarios are compared:

- *base* – a scenario, where no redundant items with different sizes are sent, is the base reference: shipment consolidation is ignored, i.e., one parcel contains one order The following scenarios extend this base scenario.
- *85 pre*, *95 pre* – a scenario, where items with a predicted fit that is lower than a certain threshold, here 85 % and 95 % respectively, are sent twice (following the "PreSend"-strategy).
- *85 preA* – a scenario, where a complete order containing one item with a predicted fit that is lower than a certain threshold, here 85 %, is sent twice (following the "PreSendAbundant"-strategy).
- *pack2* – a scenario, where two sizes are sent for each item is the reference for the maximum number of items that need to be transported.

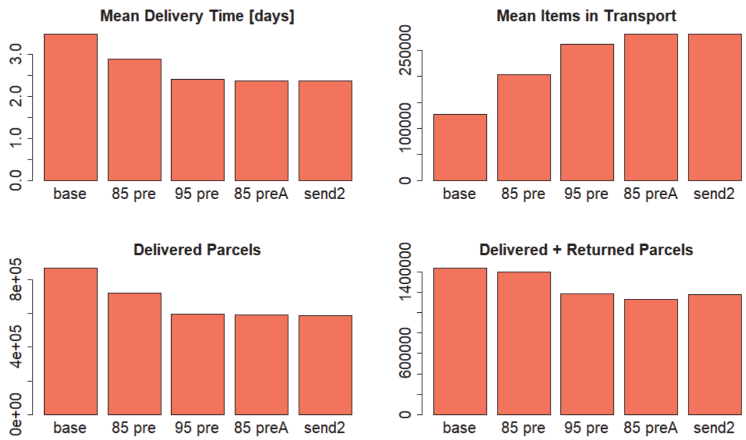

Figure 4: Summary statistics for different pre-sending strategies.

As expected, the mean number of items in transport, not including returned items, rises when choosing higher thresholds or a more aggressive preventive sending strategy, while the number of parcels sent can decrease due to the applied shipment consolidation and the absence of packaging size restrictions. The mean delivery time for the fitting item can be reduced by applying a preventive sending strategy. Interestingly, the number of parcels sent is also reduced by using the *PreSend* strategy. This indicates that the additional parcels required to return additional sent sizes are out weight significantly by the lower number of reorders for non-fitting items.

6 Summary and Further Research

Within this work, we implemented a first high-level discrete event simulation model to explore different strategies to guarantee timely delivery of items for a supply system. These strategies are based on shipment consolidation and meet the specific characteristics of the use case in employing a hybrid collection of items over a timeframe per individual and location hub and pre-sending strategies to avoid missing articles due to delivering wrong sizes. Initial experiments revealed, that applying the strategies can decrease the number of shipments as well as the delivery time of the right article.

For further exploration of strategies and their impacts, we intend to implement additional strategies and assessments for both sent and returned items: First, the option to decide on different transportation modes based on the size of collections and time constraints (see Huang et al. 2020; Romero-Silva and Mujica Mota 2022). We want to implement this in a hybrid DES-agent-based model to address shipment constraints due to shipment mode, as collections are limited in size and different modes of transportation or different dispatching rules are to be considered to evaluate whether to use external services or a transporter fleet. Second, the option to combine the first mile of return with the last mile of delivery for further scenario analysis (compare Ranathunga et al. 2022). To make decisions in the current model smarter, we can use approaches to learn what items to pool or predict patterns (see Pedrielli et al. 2016). To address not only the flexibility gained with these strategies, including an assessment of their resilience is another interesting research idea.

To make the model more realistic, several of the simplifications can be addressed. For example, the transport restrictions and effects can be modelled in greater detail and allow for an analysis of the efforts needed. Additionally, the model already includes different fit probabilities for different items - in future developments, this can be expanded by the differentiation between these items to address the problem regarding different products and different collection strategies among different products. To address individual behaviour, multiple profiles for persons that differ in their return behaviour can be included (see Abdulla et al. 2019). Additionally, warehouse and inventory considerations in the model will be implemented in the long term.

Acknowledgements

This research is part of the project LogSimSanDstBW and is funded by dtec.bw - Center for Digitization and Technology Research of the Bundeswehr. dtec.bw is funded by the European Union - NextGenerationEU.

References

Abdulla, H.; Ketzenberg, M.; Abbey, J.D.: Taking stock of consumer returns: A review and classification of the literature. Journal of Operations Management 65 (2019) 6, pp. 560–605.

Alnahhal, M.; Ahrens, D.; Salah, B.: Modeling freight consolidation in a make-to-order supply chain: A Simulation Approach. Processes 9 (2021) 9.

Huang, Q.; Ohmori, S.; Yoshimoto, K.: Incorporating transportation mode decisions into production-shipping planning: Considering shipping consolidation. Operations and Supply Chain Management: An International Journal 14 (2020) 1, pp. 62–72.

Kang, K.; Ki-sung, H.; Kim, K.H.; Lee, C.: Shipment consolidation policy under uncertainty of customer order for sustainable supply chain management. Sustainability 9 (2017) 9, without page numbers.

Ma, K.; Thomassey, S.; Zeng, X.: Development of a central order processing system for optimizing demand-driven textile supply chains: a real case based simulation study. Annals of Operations Research 291 (2020) 1, pp. 627–656.

Macioszek, E.: First and last mile delivery – Problems and issues. In: Sierpiński, G. (Hrsg.): Advanced Solutions of Transport Systems for Growing Mobility, 2018, pp. 147–154.

Memon, M.A.; Shaikh, A.; Sulaiman, A.; Alghamdi, A.; Alrizq, M.; Archimède, B.: Time and quantity based hybrid consolidation algorithms for reduced cost products delivery. Computers, Materials, & Continua 69 (2021) 1, pp. 409–432.

Nobile, T.H.; Noris, A.; Cantoni, L.; Kalbaska, N.: A review of digital fashion research: before and beyond communication and marketing. International Journal of Fashion Design, Technology and Education 14 (2021) 3, pp. 293–301.

Oehlschläger, D.; Weiße, M.; Bagge, C.; Zimmermann, C.; Glas, A.H.; Holtmannspötter, J.; Essig, M.: Testing a smartphone application for the optimisation of organisational outfitting procedures for protective clothing. In: D'Apuzzo, N. (Eds.): Proceedings of 3DBODY.TECH 2022 - 13th International Conference and Exhibition on 3D Body Scanning and Processing Technologies, Lugano, Switzerland, October 25th-26th 2022, without page numbers.

Pedrielli, G.; Vinsensius, A.; Chew, E.P.; Lee, L.H.; Duri, A.; Li, H.: Hybrid order picking strategies for fashion e-commerce warehouse systems. In: Theresa M.K. Roeder, Peter I. Frazier, Robert Szechtman, Enlu Zhou, Todd Huschka, and Stephen E. Chick (Eds.): Proceedings of the 2016 Winter Simulation Conference, Washington, DC (USA) December 11th-14th 2016, 2016, pp. 2250–2261.

Ranathunga, M.; Wijayanayake, A.N.; Niwunhella, D.: Solution approaches for combining first-mile pickup and last-mile delivery in an e-commerce logistic network: A systematic literature review. In: 2021 International Research Conference on Smart Computing and Systems Engineering (SCSE), Colombo (Sri Lanka), September 16th 2021, 2021, pp. 267–275.

Ranathunga, M.; Wijayanayake, A.N.; Niwunhella, D.: Simulation-based efficiency assessment of integrated first-mile pickup and last-mile delivery in an e-commerce logistics network. In: 2022 International Research Conference on Smart Computing and Systems Engineering (SCSE), Colombo (Sri Lanka), September 1st 2022, 2022, pp. 246–253.

Romero-Silva, R.; Mujica Mota, M.: Trade-offs in the landside operations of air cargo hubs: Horizontal cooperation and shipment consolidation policies considering capacitated nodes. Journal of Air Transport Management 103 (2022), pp. 102253.

Seewald, A.; Wernbacher, T.; Pfeiffer, A.; Denk, N.; Platzer, M.; Berger, M.; Winter, T.: Towards minimizing e-Commerce returns for clothing. In: Proceedings of the 11th International Conference on Agents and Artificial Intelligence, Prague, Czech Republic, February 19th-21st 2019, 2019, pp. 801–808.

Wei, L.; Kapuscinski, R.; Jasin, S.: Shipping consolidation across two warehouses with delivery deadline and expedited options for e-commerce and omni-channel retailers. Manufacturing & Service Operations Management 23 (2021) 6, pp. 1634–1650.

Zennaro, I.; Finco, S.; Calzavara, M.; Persona, A.: Implementing e-commerce from logistic perspective: Literature review and methodological framework. Sustainability 14 (2022) 2, pp. 911.