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An Approach to Data-Based Standardization of Automatic Miniload Warehouses

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Extended Abstract

Summary. Automatic miniload warehouses with stacker cranes are used in intralogistics processes to decouple demand from supply. However, these systems are highly complex, requiring an extensive planning phase. By identifying the commonalities among these warehouses, our research presents an approach to reduce the complexity of the planning process of automatic miniload warehouses with stacker cranes.

Keywords. database of warehouses, planning process standardization

1. Introduction

Warehouses are used in intralogistics processes to decouple demand from the supply (Arnold and Furmans 2019, 175). This task is often combined with sequencing and picking in the storage area's pre-zone (Arnold and Furmans 2019, 175).

Various solutions exist that fulfill these functions. Automatic miniload warehouses with stacker cranes are often used due to their high throughput and storage density. However, these systems are highly complex, requiring an extensive planning phase to ensure that they meet the unique requirements of each application. The complex planning process must consider a wide range of factors, including the structure of the pre-zone, the warehouse's input and output (IO) points, fire protection equipment, and the facility's layout.

Despite the complexity of these systems, our research has found that the warehouses planned in different projects with their specific requirements share a similar configuration, indicating that there may be ways to streamline the planning process and reduce the need for individualized expert knowledge.

By identifying the commonalities among these warehouses and developing an easy-to-use planning program, our research presents an approach to reduce the complexity of the planning and implementation phase of automatic miniload warehouses with stacker cranes.

2. Literature

The structure and subsystems of automatic miniload warehouses with stacker cranes are well-documented in the literature (Verein Deutscher Ingenieure 2006; Arnold et al. 2008, 660–68; Schmidt, Hahn-Woernle, and Heptner 2019, 93–105). A schematic illustration of an automatic miniload warehouse, including pre-zone and picking workstations investigated in this paper, can be found in Figure 1.

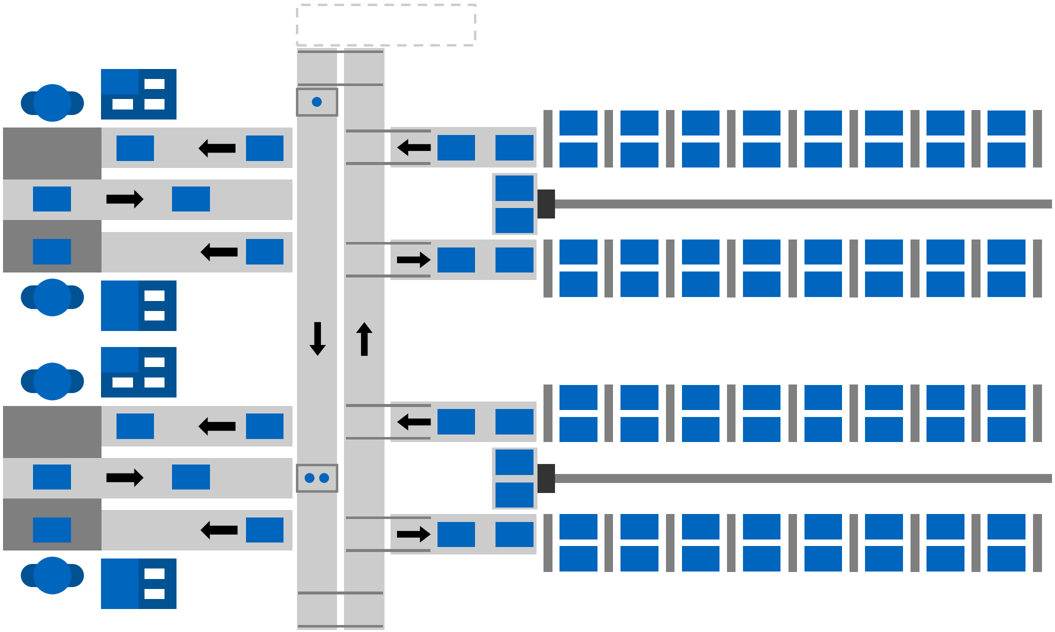

Figure 1. Schematic illustration of an automatic miniload warehouse including pre-zone and picking workstations.

The system under investigation has two options for the load units to go in and out: connected conveyors or picking workstations. When a load unit enters the system, the warehouse management system identifies the new unit and checks its weight and dimensions. Then it is conveyed to an aisle of the storage, where the automatic storage and retrieval system (AS/RS) subsequently stores the load units. After retrieving a load unit, the system conveys it to a picking workstation or a connected conveyor, where the load unit leaves the system. The loop and the conveyor IO point can also be left out for smaller systems. The workstations are then directly connected to the conveyors, leading to the automatic storage and retrieval system. (cf. Verein Deutscher Ingenieure 1994)

At the picking workstation, the order picker can take the load unit or pick the contents of multiple load units in another. Afterward, the order picker and connected conveyors can store or remove the load units.

As illustrated in Figure 1, automatic miniload warehouses consist of many modules from different manufacturers that interact in a complex way. To ensure that these systems efficiently meet their requirements, they are assembled in a systematic and elaborate planning process (Gudehus 2010, 69–70).

Gudehus splits an intralogistics system's planning and realization process into six phases, illustrated in Figure 2. In the target planning phase, the planners define the targets and requirements of the new system. Taking these as a starting point, target processes are specified in system planning, and the system's structure is developed. This structure and its submodules are further detailed in the detail planning phase and put out to tender. Based on this, manufacturers of modules and submodules can submit an offer. Finally, the system can be constructed and put into operation. (Gudehus 2010, 69–73).

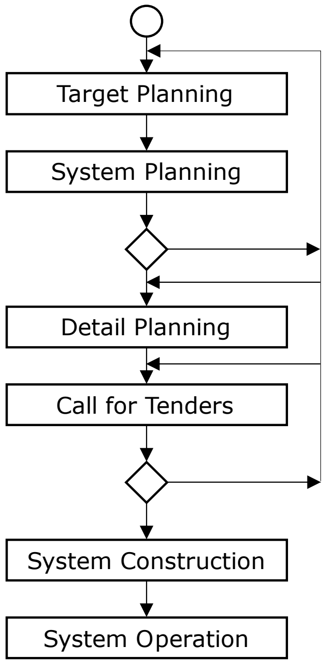

Figure 2. Planning and realization process of an intralogistics system (according to Gudehus 2010, 70)

In all planning phases, variants are elaborated, evaluated, and the most suitable one is pursued further. The requirements defined in the target planning phase are always kept in mind. If the supposedly most suitable variant proves unsuitable in further planning, it is necessary to iterate through the planning phases. Getting to the system construction phase usually takes 8 to 18 months. (Gudehus 2010, 69–73)

The entire planning process is characterized by planners making any decisions about design parameters until a warehouse meets its specifications (Gudehus 2010, 614; Roodbergen and Vis 2009, 343). In practice, specialized planning experts usually accomplish this in an experience-based and heuristic manner (cf. Baker and Canessa 2009; Atz 2016, 3).

However, the warehouses planned in these individual projects, with their specific requirements and different procedures, seem very similar in their configuration. Building on this observation, we examine how the warehouses differ and which planning parameters these characteristics depend on.

Planners are supported by extensive scientific research. It mainly focuses on the analysis of specific properties of the whole systems or their components like throughput or energy demand (Gu, Goetschalckx, and McGinnis 2010, 547; Verein Deutscher Ingenieure 2009; Bozer and White 1984; Rücker, Rief, and Fottner 2020).

Baker and Canessa (2009) state that warehouses have no comprehensive planning procedure (cf. Atz 2016). This research gap is partially addressed by Atz (2016). In his doctoral thesis, he develops a method for holistically planning automatic high-bay warehouses (Atz 2016). This method allows for designing optimal storage systems for individual requirements (Atz 2016). In addition to the technical differences between high-bay and miniload warehouses, e.g., in the fire protection requirements, he does not examine the pre-zone of the warehouse or the process-related optimization potentials that could arise from standardizing the warehouse configurations in the planning, implementation, and realization phase.

3. Methodology

Our research is based on a comprehensive database, which includes approximately 50 data sets covering the period from the past decade and has been provided by an industrial partner of our chair. Each data set contains all documents, layout plans, BOMs, and communications from the initial contact phase to the realization phase, providing a detailed record of the planning and execution of various miniload warehouse planning and realization projects.

Our analysis focuses on identifying the system boundaries and parameters, their respective characteristics, and their components. Among others, this includes the rack size and type as well as load units, the number of aisles, the position of the IO points, and the fire protection equipment of the rack. In the following steps, we will also analyze the structure of the pre-zone and express- and NIO-handling concepts.

We determine whether and to what extent these values can be standardized to reduce system complexity. Through this, we aim to reduce the number of decisions in the planning phases and the call for tender phase.

To validate our analyses, we conducted both internal and external checks. The internal validation assesses the warehouses' compatibility with our complexity-reduced system. On the other hand, external validation was performed by examining data records added later to the dataset. The validation process demonstrated that our findings apply to different miniload warehouses. Therefore, we have established a strong foundation for future research, streamlining the planning process and replacing the need for specialized experts with an easy-to-use planning program.

4. Results

First, we analyzed within which system boundaries standardization is possible. To do this, we divided the layouts of the available datasets into the following functional units: Inbound workstation, conveyance, IO-point at the conveyance loop, conveyance loop, conveyance between the loop and AS/RS, AS/RS and rack, picking stations near the IO points of the AS/RS, picking stations far away from the IO-points of the AS/RS, and outbound workstations (cf. Figure 1). The criterion for distinguishing between picking stations near and far from the IO points of the AS/RS was chosen so that the picking stations directly connected to the loop or to the conveyors that lead to the AS/RS are considered near. All other picking stations are considered far.

Next, we analyzed all possible combinations in all layouts if a direct load unit flow between two functional units is possible. The summed-up results are shown in Figure 3. To keep the figure clear, we hid all connections that occurred less than five times in our database and rounded the values.

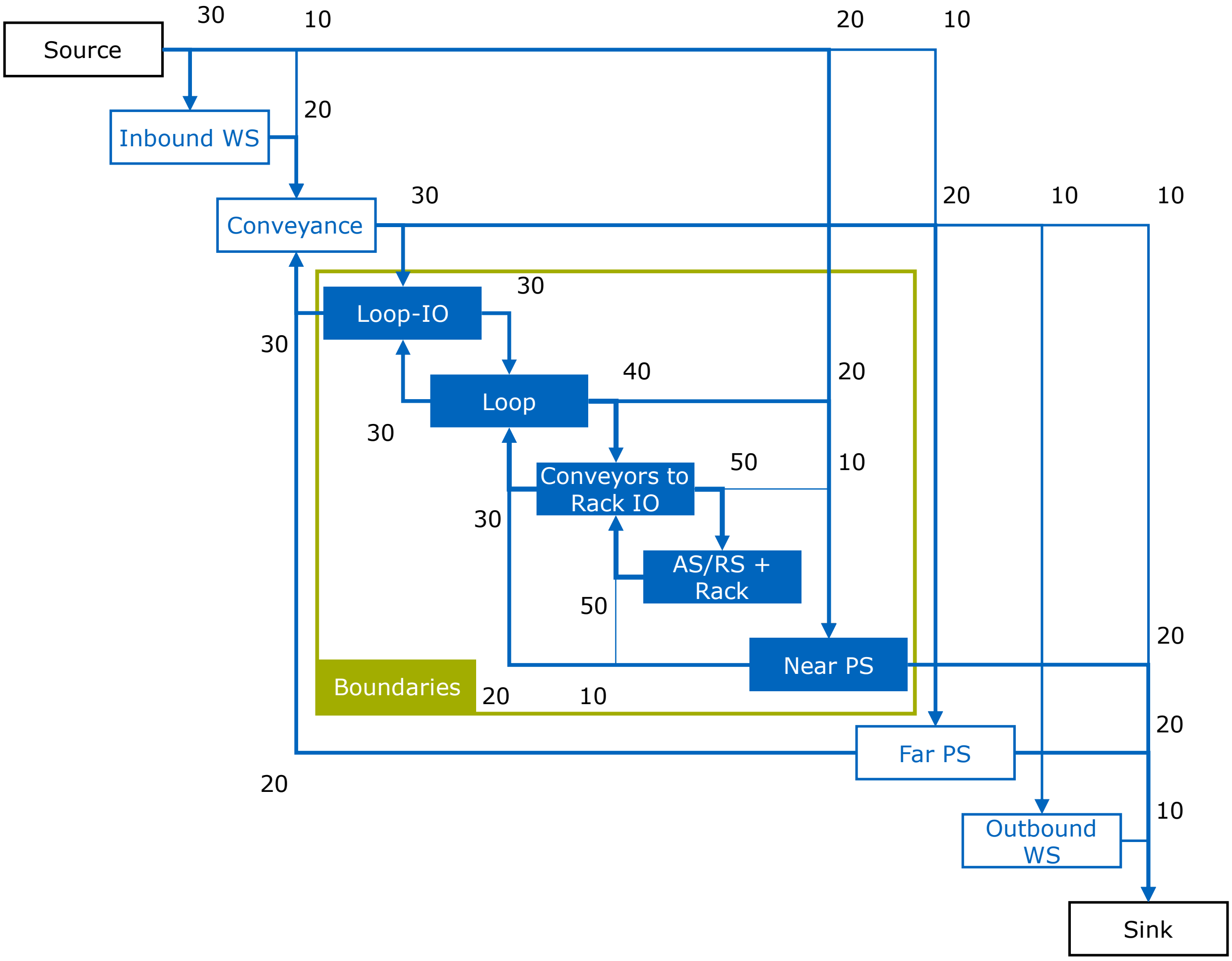

Figure 3. Analysis of the load unit flow in the systems in our database and derived system boundaries (rounded values, connections that occur less than five times in our database are hidden).

Based on this analysis, we draw the system boundaries in such a way that the systems under examination consist of IO-points at the conveyor loop, conveyance loop, conveyance between the loop and AS/RS, AS/RS and rack, as well as picking stations near the IO-points of the AS/RS. All these elements are also highly standardizable since they are in a joined and closed space. In contrast, inbound workstations, conveyance, picking stations far away from the IO points of the AS/RS, and outbound workstations are not analyzed since these are planned mainly based on individual layouts and processes.

As all the functional units under examination highly depend on the load units used, these are also assessed in this paper. As automatic miniload warehouses are often used in dispatching, it is not sufficient to examine only which load unit types are used in the overall system. It is necessary to investigate where which load unit types are used. Because of that, we analyzed the load unit types in the picking process. Which types are used as a picking source, and which are used as a picking target? The result of this analysis is shown in Figure 4 (cf. Prüfer 2021).

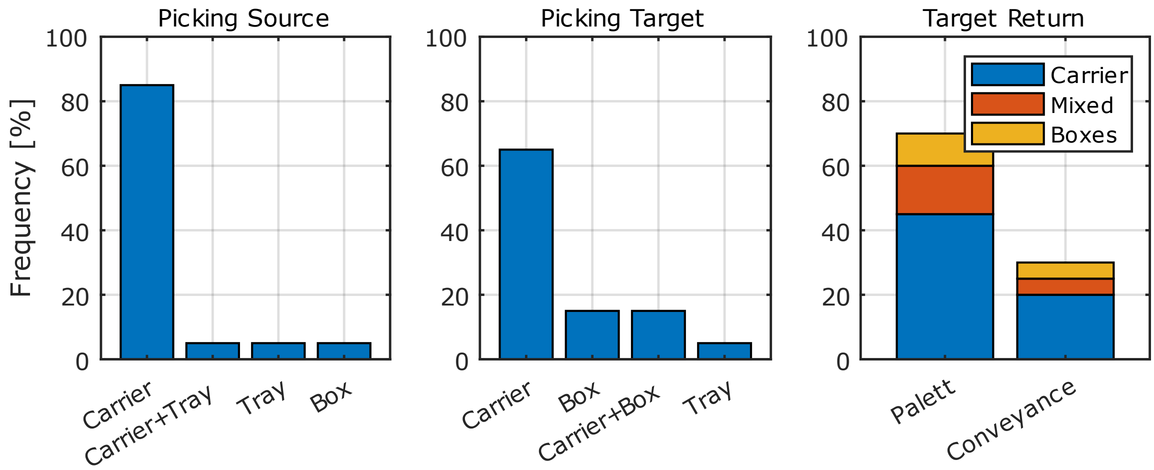

Figure 4. Analysis of the load unit types used in the systems in our database (cf. Prüfer 2021).

The load unit types used differ in their usage. For the standardization of the functional units, we suggest that only small load carriers and trays be considered, as cardboard boxes are almost entirely removed from the system directly at the picking workstation and are not returned to the system (Prüfer 2021).

This suggestion is supported because more than 95 % of the systems examined use telescopic load-handling devices that are typically only used with small load carriers and trays.

Furthermore, we analyzed the size of the small load carriers and trays in our database. We found that only VDA-compliant loading units were used (cf. Verband der Automobilindustrie e.V. 2018). Since the height of the carriers is distributed from 220 mm to 400 mm, we propose only to standardize the footprint of the loading units used and to keep their height definable in the planning process. Also, it is impossible to standardize the direction in which the KLTs are stored in the rack.

Another factor influencing the rack structure is the fire protection system. About 50 % of the systems examined are equipped with a sprinkler system. Therefore, providing an optional sprinkler system in the standardized miniload warehouse concept is necessary.

In summary, we found multiple possibilities to simplify the planning process of an automatic miniload warehouse. Some parameters can be assumed to be invariant. In other cases, we identified different options that must be provided in the planning process. In these cases, we suggest developing algorithms to support the planners. One example of a practical algorithm distributes the driving heights and sprinklers over the height of the warehouse so that the space is used as efficiently as possible.

5. Conclusion

In this approach to standardize an automatic miniload warehouse, we analyzed a database of warehouses provided by an industrial partner of the chair. First, we examined which functional units of a warehouse can be standardized. Next, we analyzed which load unit types are used where in the systems under examination.

By doing so, we could identify parameters that can be standardized to streamline the planning process of an automatic miniload warehouse. We also found parameters that must be definable and options that must be selectable in the planning process. We validated these findings externally by examining data sets added later to the dataset.

Our further research tasks will focus on further analysis of the datasets and on developing an easy-to-use planning tool based on the analysis findings.

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