

Warehouse Layout Optimization Based on ERP-Driven Modeling: A Case Study from the Wood Industry

Vera Suri ,* Endre Magoss , and János Suri

In the wood industry, warehouse layout decisions have a strong impact on production efficiency and workplace safety. This study presents a methodology that combines ERP-based historical movement data with measured process times to evaluate alternative warehouse layout versions. As a first step, products were grouped, their packaging and storage types were identified, and stock demand was calculated based on average and percentile values. A movement model was then used to assess layout options based on measured handling times and transport distances. Four layout versions were presented to the company management. For each version, the total daily net material handling time and required storage capacity were determined. The results showed that the originally planned block storage layout (V2) had a medium handling time and good feasibility but raised safety concerns. The V4 layout provided the most balanced option in terms of safety and capacity, while the finally selected V3 version—with a 4-meter aisle width—offered the lowest total handling time, which was a priority due to high production volume and fast warehouse servicing needs. This research demonstrates how can the Excel-based numerical modeling built on ERP data and process measurements, support warehouse layout decisions and improve operational performance and strategic planning.

DOI: 10.15376/biores.21.3.6924-6942

Keywords: Warehouse layout optimization; Woodworking industry; ERP data; Process modelling; ABC analysis; Percentile-based capacity planning; Material handling efficiency

Contact information: University of Sopron, Faculty of Wood Engineering and Creative Industries, Sopron, 9400 Hungary; * Corresponding author: suri.vera@uni-sopron.hu

INTRODUCTION

The study presents a warehouse design and optimization project conducted for a domestic-based wood industry company. The company makes construction products and is part of a multinational group, with several sites in Hungary. The manufacturing company is a subsidiary of a large multinational manufacturer specializing in high-volume construction products. The newly built warehouse facility, which is the subject of this study, covers an area of approximately 6,000 m². The hall was designed as a central service element for the assembly plants, where a wide range of unitized materials is managed. In recent years, the company has experienced a continuous increase in production volume, which has made it necessary to build and commission new halls and facilities. One of the most recent steps was the construction of a warehouse building intended to serve the production halls. The warehouse was originally planned based on current customer needs, production volumes, and delivery conditions. Construction had already started, the plans were finalized. However, customer demand continued to grow. Even though the company had included some reserve capacity, they began to question whether the planned internal

layout would be enough for future production needs. Warehouse design is widely recognized as a strategic factor influencing operational efficiency, material flow performance, and long-term logistics costs within manufacturing systems (Rouwenhorst *et al.* 2000; Baker and Canessa 2009; Gu *et al.* 2010).

The aim of this research was to develop and evaluate alternative warehouse layout versions for the company's new facility. The analysis is based on one year of real material movement data exported from the ERP system, modeled in Excel with integrated internal transport route coordinates. Each layout version is evaluated using quantitative criteria such as workplace safety, warehouse operating efficiency, space utilization, and investment requirements.

Research Questions

1. How can historical movement data be used as an evaluation tool for objectively comparing warehouse layout alternatives?
2. What impact does product categorization and storage strategy have on internal material handling time and resource allocation?
3. How can an ERP-driven, spreadsheet-based Decision Support System (DSS) provide a reliable and transparent framework for strategic warehouse layout optimization?

Literature Review

The manufacturing processes of wood industry companies strongly depend on the efficiency of material handling, storage strategies, and the optimization level of warehouse layout (Frazelle 2002; Tompkins *et al.* 2010; Heragu 2016). According to the literature, Excel-based decision support systems (DSS) provide cost-effective and flexible solutions for small and medium-sized enterprises (Sharer *et al.* 2022). The increasing availability of enterprise resource planning (ERP) systems has further enhanced the use of operational data in warehouse planning and logistics decision-making (Davenport 1998; Kelle *et al.* 2019). Several studies highlight that Excel data can be integrated with spatial coordinate systems, thereby enabling the development of simulation models for the quantitative comparison of alternative warehouse layouts. For example, the procedures presented by Hapsari *et al.* (2025) evaluate inventory using ABC analysis and then group items by type. The approach developed by Vieira *et al.* (2015) is especially innovative, as it combines Excel-based data input with a Simio-based simulation environment to generate automated 3D warehouse models. This method supports optimization not only through calculations but also through visual representation, which is particularly useful for management-level decision-making.

Many authors offer specific methodological examples for optimizing service logistics and comparing layout variants. For instance, Qiu and Mikkonen (2004) examined the route optimization of wood-based raw materials using GIS and LINDO optimization systems. Önüt *et al.* (2008) focused on the optimal layout of multi-level warehouse shelving systems to reduce annual inventory costs. Their study applied a particle swarm optimization (PSO) algorithm, primarily as a theoretical model for addressing the complexity of layout planning, rather than for direct practical implementation. Among theoretical models, there are also approaches that optimize layout and operational control policies together to achieve significant performance improvements. In a Dutch case study, such combined optimization reduced travel distances by up to 53% (Roodbergen *et al.* 2015). Discrete event simulation models (Gagliardi *et al.* 2007) and DOE-based approaches (Jeon *et al.* 2023) are particularly relevant when time-based processes and

waiting times play a key role in evaluation.

Other authors use quantitative models to assess the impact of layout-related decisions, based on multi-criteria performance indicators, to support managerial decision preparation (Zhou *et al.* 2022; Derpich *et al.* 2022). Excel-based simulations provide a well-structured framework for this, especially when real company data—such as ERP-derived movement logs — are available. Lu *et al.* (2015) present an order-picking optimization methodology that outperforms many advanced strategies. Efficient order-picking and routing policies have long been identified as major determinants of warehouse performance and labor productivity (Petersen 1999; de Koster *et al.* 2007). Although not developed specifically for the wood industry, the results are applicable to sectors where input-output cycles can be standardized.

Warehouse layout optimization has been investigated from several methodological perspectives, which can be broadly categorized into four main research streams.

The first group focuses on analytical and algorithm-based optimization methods, including metaheuristics, mathematical programming, and swarm intelligence approaches (Önüt *et al.* 2008; Roodbergen *et al.* 2015). These studies typically aim to identify globally optimal layouts under predefined assumptions. While they provide strong theoretical performance improvements, their industrial implementation often requires simplified system representations and specialized optimization expertise.

A second stream applies simulation-based approaches, such as discrete-event simulation or digital twin environments, to analyze operational performance under dynamic conditions (Gagliardi *et al.* 2007; Vieira *et al.* 2015; Jeon *et al.* 2023). Simulation models enable detailed time-based evaluation and visualization, but they usually involve significant modeling effort, dedicated software environments, and higher implementation costs.

A third research direction emphasizes logistics decision-support systems integrating operational data, including GIS-based logistics planning or performance evaluation models (Qiu and Mikkonen 2004; Zhou *et al.* 2022; Derpich *et al.* 2022). These approaches highlight the importance of combining quantitative indicators with managerial decision-making criteria.

Finally, an emerging practical line of research investigates accessible data-driven tools, particularly Excel-based decision support solutions for industrial environments (Sharer *et al.* 2022; Hapsari *et al.* 2025). These methods are especially relevant for manufacturing companies where rapid implementation, transparency, and adaptability are more critical than theoretical optimality.

Despite the extensive literature, relatively few studies demonstrate how historical ERP movement data can be systematically transformed into a quantitative warehouse layout evaluation model without relying on complex simulation platforms or advanced optimization algorithms. Moreover, limited attention has been paid to industries such as woodworking, where mixed storage logic, large material units, and safety constraints strongly influence layout feasibility.

Comprehensive reviews of warehouse design and control research have consistently emphasized the need to integrate layout planning, storage assignment, and operational policies within a unified decision framework (Rouwenhorst *et al.* 2000; Gu *et al.* 2010).

Research Gap and Contribution of the Study

While advanced warehouse planning methodologies are available, many industrial projects still require practical solutions that can be implemented without extensive simulation expertise or dedicated optimization software (Heragu 2016; Bartholdi and Hackman 2019).

Based on the reviewed literature, a gap can be identified between highly sophisticated optimization methodologies and practically implementable industrial decision-support tools. Many existing studies either focus on theoretical optimization models or require advanced simulation environments that may not be accessible for small and medium-sized manufacturing companies.

In contrast, industrial practitioners often need transparent, rapidly deployable methods that rely on already available company data and support managerial decision-making under real operational constraints.

The present study addresses this gap by proposing a warehouse layout evaluation methodology that:

- directly utilizes one year of ERP-derived material movement history,
- integrates shopfloor-measured handling processes into a coordinate-based movement model,
- applies percentile-based capacity planning linked to layout design decisions, and
- enables objective comparison of layout alternatives using a widely accessible Excel-based modeling environment.

Rather than searching for a mathematically optimal layout, the study contributes a practical data-driven decision-support framework that bridges academic warehouse optimization research and real industrial implementation in the wood industry.

EXPERIMENTAL

The research methodology was based on the processing of one year of historical movement data extracted from the ERP system, supplemented with on-site process observations and time measurements. The dataset for the analyzed period contained more than 20,000 material movement records. The Excel-based decision support system is capable of processing reliable transactional data derived from a large-scale corporate ERP environment. Similar data-driven approaches have become increasingly important within the context of digitalized logistics and Industry 4.0 environments (Wang *et al.* 2016; Hofmann and Rüscher 2017). While complex simulation tools often require simplified data, this model utilizes a full year of actual movement records, thereby ensuring that the results reflect real industrial throughput. As emphasized by Sharer *et al.* (2022), such models provide the necessary transparency for management-level strategic decisions, where the primary objective is to evaluate structural layout alternatives based on historical evidence rather than short-term operational fluctuations. During the modeling process, significant attention was paid to data cleaning: based on the Bills of Materials (BOM lists), approximately 3,000 SKUs (parts and finished goods) associated with the servicing of the investigated assembly hall were filtered. Furthermore, by analyzing movement codes, bypass transactions—items that physically bypass the warehouse—were identified and handled separately to avoid distorting the warehouse load data. Products were first grouped into categories, then linked to packaging and storage types, and the physical characteristics

of the storage units formed from packaging units were determined. Using these data, two models were developed: space requirement model and coordinate-based material handling model.

Assumptions and Operational Constraints

1. It was assumed that the incoming of materials and the way they are used would continue according to the current schedule.
2. Although a significant volume increase has been realized in recent years, it was assumed that while storage capacity should be planned with a suitable buffer, further sharp increases are not realistic under the current conditions.
3. It was assumed that the packaging method and units of incoming materials would stay the same. However, one goal of the project was to identify if changes were needed to improve warehouse operations.
4. In the warehouse, products did not have fixed dedicated locations in general – only a few key products did. However, in most cases, similar or related products were stored close to each other, and this expectation remains a basic requirement.
5. In addition to rack storage, block storage was also typical, meaning that heavy, hard-to-move raw materials were not stored on shelves but stacked on the floor in blocks.
6. It was clarified at the beginning of the project that the material handling equipment and systems in use would not change significantly – the goal was not to create a completely new logistics system that would disrupt existing operations.
7. The current production management system, as well as the warehouse servicing methods and material tracking, would remain unchanged.

Data Sources

The analysis was based on material movement data extracted from the company's ERP system, covering the previous year. ERP systems provide a reliable source of transactional information that can support operational analysis, logistics planning, and performance evaluation across supply chains (Davenport 1998; Kelle *et al.* 2019). These records included the timestamp of each movement, the product ID and quantity moved, and the direction of the movement.

To make the model workable, the first step was to group the products into product categories. In certain cases, the ERP system lacked comprehensive logistical classifications; therefore, products were grouped based on their shared physical attributes, packaging characteristics, and handling requirements. This aggregation was necessary to transform hundreds of unique SKUs into manageable units, enabling the systematic assignment of dimensions and packaging data required for the model's calculations. This classification later became one of the model's core building blocks. After that, the following characteristics were defined and linked to each product category: (1) packaging types (*e.g.*, box), (2) quantity of product per package, (3) storage types (*e.g.*, pallet), (4) number of packaging units per storage unit, and (5) physical dimensions of each storage type.

RESULTS AND DISCUSSION

Space Requirement Model

The purpose of the space requirement model was to calculate warehouse capacity needs as accurately as possible, based on yearly inventory movements, daily fluctuations, and a security level defined by the company. The warehouse primarily stores in-house manufactured wood components and various purchased parts intended for final assembly. These items are handled as standardized unit loads (typically on pallets or in crates) to ensure efficient storage and movement. Individual wood component lengths typically range from 500 mm to 1,600 mm, but for modeling purposes, the dimensions of the standardized transport units were used as the primary basis, as these determine the space requirements and movement characteristics within the racking system. Using opening stock levels and annual movement data from the production management system, daily stock levels were calculated by storage type. From this, average and maximum inventory levels were derived for each storage category.

To determine the appropriate safety stock levels, a percentile-based method was applied (Table 1). Daily stock levels were sorted in descending order, and the practically adjusted average stock levels (+20%, and +35% for certain product groups) were examined to observe how they covered warehouse needs. According to this analysis, the adjusted levels provided sufficient capacity for about 83% of the days. The 83% coverage (percentile) applied in the model represents a strategically optimal safety level for warehouse sizing. This value was derived from the inventory adjustments (+20 to 35%) based on the multi-year practical experience of the investigated multinational corporation. The results of the calculation are consistent with the inventory buffering principles presented in national literature, where a service level of 80% was considered appropriate for determining safety stock based on case study data. This level ensures that the warehouse can accommodate daily fluctuations for the vast majority of the year, while avoiding the exponential cost increases and space underutilization associated with higher levels (*e.g.*, above 95%). Consequently, the 83% value validates the practical adjustments applied by the company, confirming their professional soundness in strategic warehouse planning. For peak demands above this level, temporary floor storage is recommended, as these situations only occur occasionally and for short periods.

Table 1. Percentile-based Calculation of Safety Stock Levels

Type of Containers	365	364	363	362	361	360	359	358	357	356	355	354	353	352
	100%	100%	99%	99%	99%	99%	98%	98%	98%	98%	97%	97%	97%	96%
L51	125	125	125	125	125	125	124	120	109	105	105	105	102	101
L52	518	498	494	494	494	492	489	482	478	475	474	471	471	467
L53	230	220	218	205	205	205	200	200	200	200	199	199	199	198
FAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAH	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ST1	14	13	13	13	13	13	13	13	13	13	13	13	13	13
ST2	136	136	136	133	131	131	131	131	131	128	128	126	126	125
ST3	89	77	77	77	77	76	76	76	76	75	75	75	75	75
ST4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LK1	125	125	125	124	124	124	124	124	124	124	124	124	124	124
LK2	48	48	48	48	48	48	48	48	48	48	48	48	48	48
FR1	94	93	92	91	91	90	90	90	90	90	90	90	90	90
BG1	1549	1496	1492	1489	1455	1444	1444	1404	1403	1400	1398	1398	1398	1398
BG2	813	805	804	804	802	787	787	787	787	787	787	787	779	778
BG3	746	742	723	710	709	709	709	683	670	647	646	646	642	624
BG4	519	517	517	517	516	515	481	477	303	299	299	299	295	292
BG5	251	246	246	246	233	233	231	231	230	229	227	224	224	223
BG6	125	124	124	118	118	115	115	115	115	113	113	113	113	112
BG7	62	62	61	59	58	58	57	57	57	57	55	54	54	54
KT1	81	76	75	74	74	74	74	74	73	73	73	73	72	71
KT2	63	60	60	60	60	59	59	59	59	58	58	58	58	57
KT3	59	57	56	56	56	55	54	54	53	53	52	52	52	52
KT4	49	49	48	48	47	46	46	46	46	45	45	45	44	44
KT5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ER1	44	43	41	39	39	39	38	38	38	37	37	37	36	36
IBC	75	75	75	75	75	75	75	75	75	75	75	75	75	75

Based on these results, warehouse space requirements were calculated monthly in square meters, cubic meters, and in shelf-leg units, with Fig. 1 showing only the values expressed in shelf-leg units (Fig. 1).

In parallel, an ABC analysis was conducted for both products and storage types to identify product categories with the highest space demand and most frequent movements. This supported both zone layout design and product placement planning. The ABC analysis used annual movement and inventory data from the ERP system. Its purpose was to categorize products based on movement frequency, which helped to design logical warehouse zones, plan high-turnover items closer to picking areas, and minimize travel distance and service time within the warehouse.

Products were classified into three groups: **A category**, highest movement frequency (top third of all movements); **B category**, medium frequency (middle third); and **C category**, low frequency (bottom third). The ABC results made it possible to establish a priority order for zone placement. The goal was not to just optimize the order of product access and storage logic. The exact space requirements were also calculated for each storage type, which had to be placed within the available warehouse area during the layout design phase. The specific zone layouts and warehouse arrangement variants were developed in collaborative sessions, based on expert decision-making, rather than automatic calculations.

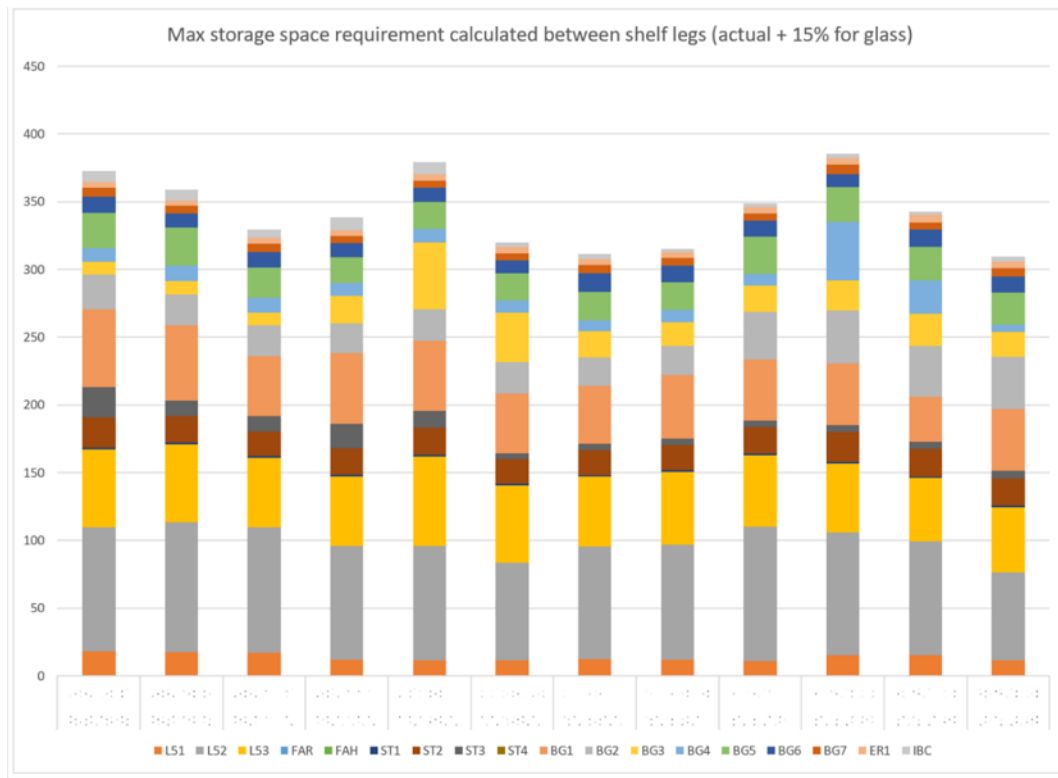


Fig. 1. Monthly warehouse space requirement

Zone Allocation and Layout Versions

For the purpose of comparison, the following criteria were defined where the layout versions could differ:

- spatial positioning of high-turnover product groups (e.g. proximity to entry points),
- storage logic (shelving, block stacking, mixed),
- the main directions of the route network and the structure of priority traffic zones,
- the number of dedicated storage locations and their product assignments.

In designing the layout alternatives, special attention was paid to ensuring that each version could be implemented with minimal cost (number of racks, changes to material handling equipment), while still using the company's current tools and ways of working with materials. The examined layouts are therefore not theoretical concepts, but practical alternatives tailored to the actual manufacturing, storage, and logistics environment. During the design process, many different layout variants were created. In the end, four were selected that the project team found suitable based on their goals (The detailed comparison of these versions is presented in the *Results* section):

- **V1:** rack layout with protected column rows (Fig. 2),
- **V2:** block stacking layout (initial concept) (Fig. 3),
- **V3:** combined rack and block stacking system (Fig. 4),
- **V4:** optimized rack layout with protected columns and well-designed transfer zones (Fig. 5).

V1 3m
464

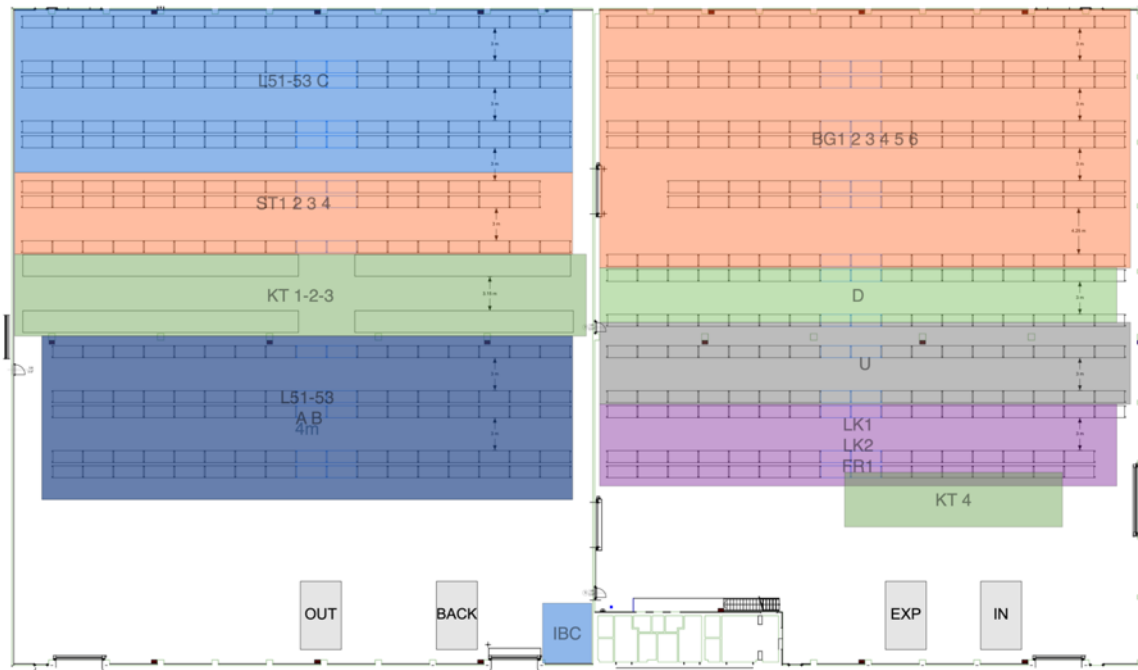


Fig. 2. V1: Racking layout with protected column rows

V2
181,8

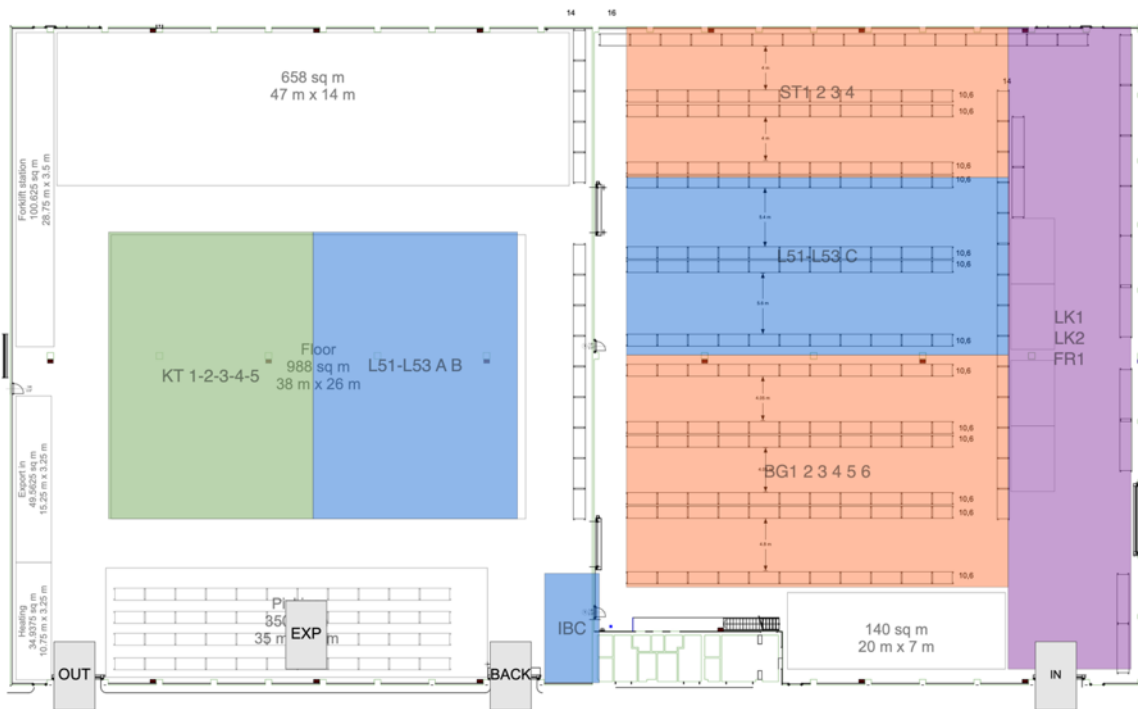


Fig. 3. V2: Block stacking layout

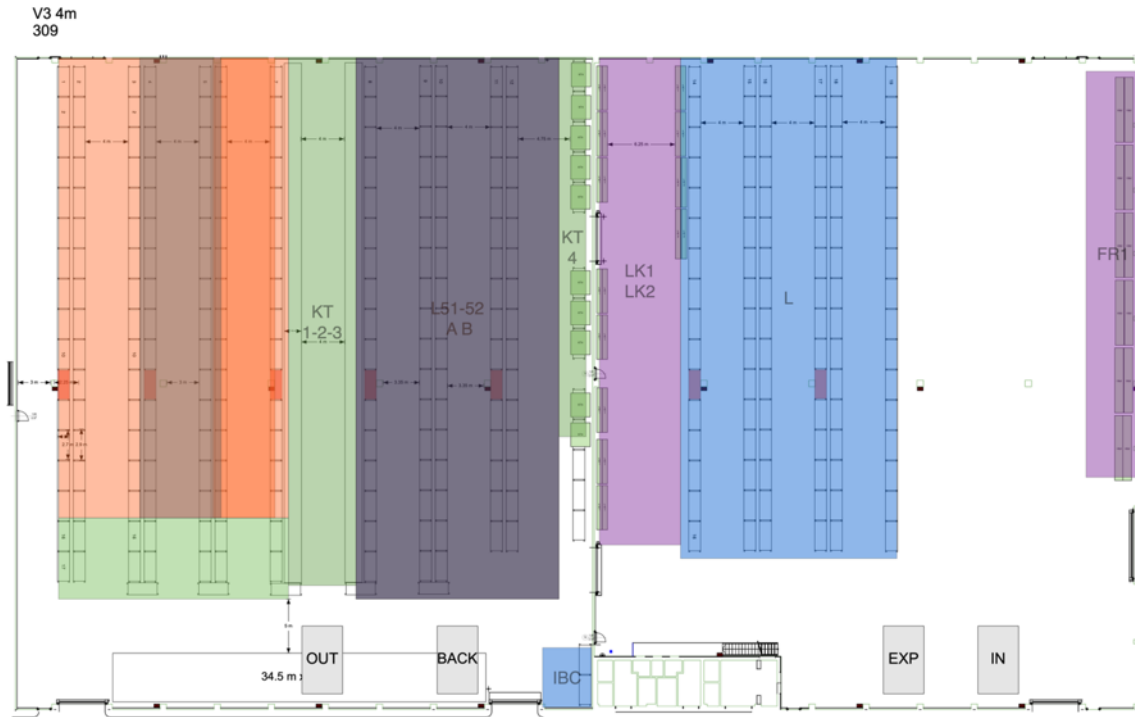


Fig. 4. V3: combined racking and block stacking system

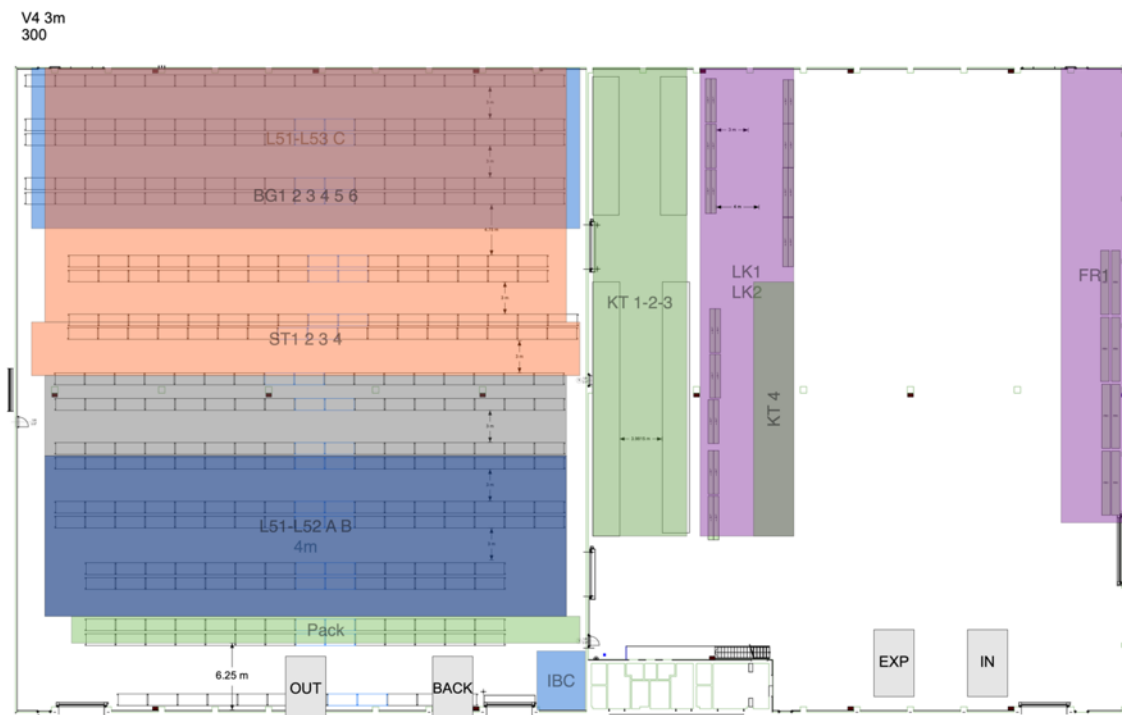


Fig. 5. V4: optimized racking layout with protected columns and transfer zones

Coordinate-Based Material Handling Model

Time-based evaluation of warehouse operations is commonly supported by simulation and process modeling techniques that represent material flows and resource utilization (Banks *et al.* 2010; Bartholdi and Hackman 2019).

The purpose of the material handling model was to calculate the performance (in terms of time and route length) of material movements for each layout version, based on actual ERP data. The model was built on the technologization of movement types. ERP data contained only accounting records of movements, without showing the differences between real handling types. Based on recurring movement patterns, handling categories such as inbound storage, outbound dispatch, internal relocation, *etc.*, were defined. The ERP system recorded movement codes along with source and destination location codes. Decoding these location identifiers helped to classify the relevant types of physical movements. Because the records included only quantities and product IDs, one ERP movement entry often represented several real-life handling tasks or forklift trips. In some product groups, multiple products were transported together on a single pallet, using one handling event. After this step, products were linked to specific types of physical movement. At that point, detailed technologization of each movement type became necessary. To support this, detailed on-site stopwatch measurements process observations were conducted in real settings, recording the handling operations (*e.g.*, storing, dispatching, transferring), then breaking them down into sub-tasks and measuring the time required for each (Table 2). This approach ensured that the model parameters reflect real operational conditions. Two main categories of handling steps were identified:

- Distance-based steps: operations where time depends on the distance covered, *e.g.*, a forklift moving goods from one point to another.
- Fixed-time steps: tasks with constant time requirements, independent of distance, *e.g.*, recording the transaction, placing items on a shelf, or lifting.

Table 2. Technologization of Movement Types

Type of Container	Move indoor with goods	Move indoor empty	Forklift lift up with goods	Forklift lift up empty	Forklift down with goods	Forklift down empty	Data input shelf	Data input floor	Manipulation in shelf First	Manipulation in shelf Middle	Manipulation in shelf High	Manipulation in floor First	Manipulation in floor Middle	Manipulation in FIFO	Manipulation out shelf First	Manipulation out shelf Middle	Manipulation out shelf High	Manipulation out floor First	Manipulation out floor Middle
	m/s	m/s	m/s	m/s	m/s	m/s	s	s	s	s	s	s	s	s	s	s	s	s	s
L51	1.39	2.22	0.33	0.36	0.38	0.4	16	10	17.37	17.37	29	18.43	31	60	12	14	16	16.75	18
L52	1.39	2.22	0.33	0.36	0.38	0.4	16	10	17.37	17.37	29	18.43	31	60	12	14	16	16.75	18
L53	1.39	2.22	0.33	0.36	0.38	0.4	16	10	17.37	17.37	29	18.43	31	60	12	14	16	16.75	18
FAR	1.39	2.22	0.21	0.56	0.31	0.38	18	10	14	19.63	29	20	25	60	12	14	16	12	18
FAH	1.39	2.22	0.21	0.56	0.31	0.38	18	10	14	19.63	29	20	25	60	12	14	16	12	18
ST1	1.39	1.67	0.25	0.25	0.27	0.27	18.76	10	14	19.63	29	20	25	60	12	14	16	15	30
ST2	1.39	1.67	0.25	0.25	0.27	0.27	18.76	10	14	19.63	29	20	25	60	12	14	16	15	30
ST3	1.39	1.67	0.25	0.25	0.27	0.27	18.76	10	14	19.63	29	20	25	60	12	14	16	15	30
ST4	1.39	1.67	0.25	0.25	0.27	0.27	18.76	10	14	19.63	29	20	25	60	12	14	16	15	30
LK1	1.25	2.22	0.33	0.56	0.31	0.42	23.5	10	11	12	13	20	25	60	10	15	20	12	15
LK2	1.25	2.22	0.33	0.56	0.31	0.42	23.5	10	11	12	13	20	25	60	10	15	20	12	15
FR1	1.10	2.22	0.33	0.56	0.31	0.42	23.5	10	11	12	13	20	25	60	10	15	20	12	15
BG1	1.39	2.22	0.21	0.56	0.31	0.38	18	10	14	19.63	29	20	25	60	12	14	16	12	16
BG2	1.39	2.22	0.21	0.56	0.31	0.38	18	10	14	19.63	29	20	25	60	12	14	16	12	16
BG3	1.39	2.22	0.21	0.56	0.31	0.38	18	10	14	19.63	29	20	25	60	12	14	16	12	16
BG4	1.39	2.22	0.21	0.56	0.31	0.38	18	10	14	19.63	29	20	25	60	12	14	16	12	16
BG5	1.39	2.22	0.21	0.56	0.31	0.38	18	10	14	19.63	29	20	25	60	12	14	16	12	16
BG6	1.39	2.22	0.21	0.56	0.31	0.38	18	10	14	19.63	29	20	25	60	12	14	16	12	16
BG7	1.39	2.22	0.21	0.56	0.31	0.38	18	10	14	19.63	29	20	25	60	12	14	16	12	16
KT1	1.39	2.22	0.29	0.56	0.31	0.33	18	10	14	19.63	29	20	21	60	12	14	16	12	37
KT2	1.39	2.22	0.29	0.56	0.31	0.33	18	10	14	19.63	29	20	21	60	12	14	16	12	37
KT3	1.39	2.22	0.29	0.56	0.31	0.33	18	10	14	19.63	29	20	21	60	12	14	16	12	37
KT4	1.39	2.22	0.29	0.56	0.31	0.33	18	10	14	19.63	29	20	21	60	12	14	16	12	37
KT5	1.39	2.22	0.29	0.56	0.31	0.33	18	10	14	19.63	29	20	21	60	12	14	16	12	37
ER1	1.39	2.22	0.21	0.56	0.31	0.38	18	10	14	19.63	29	20	25	60	12	14	16	12	16
IBC	1.39	2.22	0.21	0.56	0.31	0.38	18	10	14	19.63	29	39.5	39.5	60	12	14	16	13	16

These technological time measurements and routes formed the foundation of the material handling model, enabling objective, time-based comparisons between layout versions. An important experience was that calculated times needed adjustment based on actual implementation. For example, the modeled time for storing small items such as screws or clips—calculated per packaging unit—was unrealistic. Shopfloor observation showed that in practice, full pallets are brought to the rack area, and only the racking step

is performed item by item. Accordingly, for such items, the model's time values were corrected using a shopfloor-observed adjustment factor, to reflect reality more accurately.

Next, the four layout versions (V1 to V4) were drawn using the TouchDraw program. In order to calculate time based on movement speed, a coordinate-based layout plan was needed that included the movement paths (Fig. 6). For each product group and each version, a path was defined that included an entry point, an exit point, and several intermediate locations. A spatial coordinate system was applied to the warehouse floor layout, where zones, storage types, and entry/exit points were assigned fixed coordinates. Material handling paths were modeled in this space, allowing every ERP movement to be interpreted as a physical route, and enabling the calculation of total distances and required times.

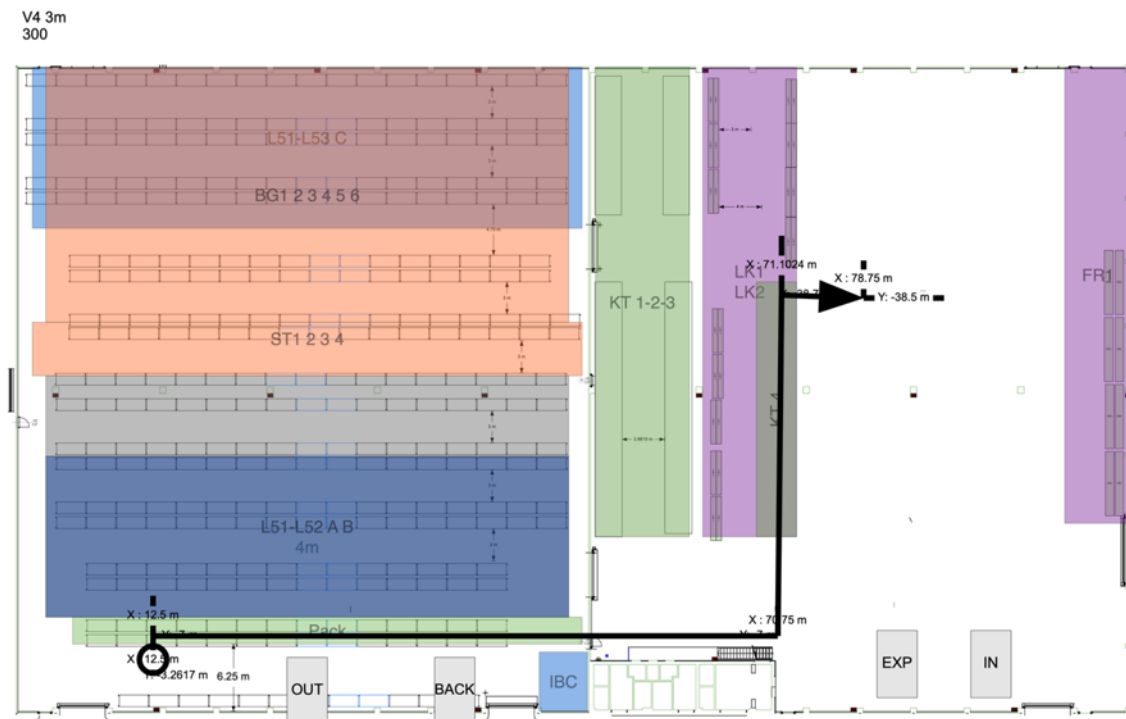


Fig. 6. Material handling paths

Table 3. Calculation of Material Handling Time Requirements

	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ
	Stock	Type of container	Storage quantity	Number of occupied storages	Packaging type	Packaging quantity	Count of moving in packages	Workday	Shift	Type of material	ABC	Type&Materialtype &ABC	V1	V2	V3	V4
73		FAR	200	1	P2T	200	1	2022.08.31	N			FAR	0	0	0	0
74		BG3	440	1	BG3	20	2	2022.08.31	N		C	BG3_C	0,1097	0,0971	0,0651	0,0833
75		BG5	168	4	BG5	168	4	2022.08.31	N		C	BG5_C	0,2194	0,1942	0,1302	0,1667
76		BG5	168	2	BG5	168	2	2022.08.31	N		C	BG5_C	0	0	0	0
77		BG2	420	1	BG2	420	1	2022.08.31	N			BG2	0	0	0	0
78		BG1	240	1	BG1	240	1	2022.08.31	N		C	BG1_C	0,0548	0,0486	0,0326	0,0417
79		BG2	210	1	BG2	210	1	2022.08.31	N			BG2	0	0	0	0
80		L52	48	1	UV3	48	1	2022.08.31	N		C	L52_C	0,0577	0,0481	0,0416	0,0364
81		L52	22	2	UV3	22	2	2022.08.31	N		A	L52_A	0,0635	0,0564	0,0633	0,0467
82		L52	22	1	UV3	22	1	2022.09.01	D		A	L52_A	0,0317	0,0282	0,0317	0,0234
83		BG5	600	1	BG5	600	1	2022.09.01	D		A	BG5_A	0,0496	0,0421	0,0326	0,0365
84		BG5	600	1	BG5	600	1	2022.09.01	D		A	BG5_A	0,0496	0,0421	0,0326	0,0365
85		L52	24	5	UV2	24	5	2022.09.01	D		C	L52_C	0,2887	0,2406	0,2078	0,1818
86		KT4	115	1	KT4	115	1	2022.09.01	D			KT4	0,0407	0,03	0,0372	0,0408
87		KT2	115	1	KT2	115	1	2022.09.01	D			KT2	0,0425	0,03	0,0308	0,0394
88		KT1	115	2	KT1	115	2	2022.09.01	D			KT1	0,085	0,0601	0,0616	0,0788
89		BG5	40	1	BG5	40	1	2022.09.01	D		C	BG5_C	0,0548	0,0486	0,0326	0,0417
90		BG5	40	1	BG5	40	1	2022.09.01	D		C	BG5_C	0,0548	0,0486	0,0326	0,0417
91		L52	24	3	UV2	24	3	2022.09.01	D		C	L52_C	0,1732	0,1444	0,1247	0,1091
92		BG2	40	1	BG2	40	1	2022.09.01	D		C	BG2_C	0,0548	0,0486	0,0326	0,0417
93		KT4	115	1	KT4	115	1	2022.09.01	D			KT4	0,0407	0,03	0,0372	0,0408
94		BG5	713	1	BG5	713	1	2022.09.01	D		C	BG5_C	0,0548	0,0486	0,0326	0,0417
95		ST3	2700	1	ST3	300	1	2022.09.01	D			ST3	0,0553	0,0625	0,0513	0,0322
96		ST3	2700	1	ST3	300	1	2022.09.01	D			ST3	0,0553	0,0625	0,0513	0,0322

With TouchDraw, a map of storage type placements was created for each layout version, including all start, end, and intermediate points. Using the exported coordinates, each storage type could be assigned a specific access path. This made it possible to assign the following data to each movement event in the full-year ERP dataset (product by product): the route length corresponding to the given layout version, from which movement time was calculated based on typical travel speeds; and the fixed manipulation times associated with the process (*e.g.*, lifting, recording, inspection).

These calculated values were aggregated for each layout version to determine the daily, weekly, and monthly material handling time requirements, representing the operational workload of the layout; and the required storage area based on the results of the storage demand model (Table 3).

Evaluation Criteria

The layout versions were evaluated based on multiple aspects. Multi-criteria warehouse evaluation approaches are consistent with established warehouse design methodologies, which recommend balancing operational efficiency, investment costs, storage capacity, and safety considerations (Baker and Canessa 2009; Heragu 2016). Defining the criteria relied on operational factors that are also critical in the company's daily practice. This ensured that the developed model could be used for real decision support. To provide a transparent comparison, each layout was assessed using a qualitative scale (OK – favorable, MED – medium/conditional, NOK – unfavorable) across key operational dimensions. The layout versions were compared along the following dimensions:

- Operational efficiency of the warehouse – for each version, we calculated the required net daily material handling time (in work hours).
- Warehouse utilization – to compare the alternatives, space utilization indicators were used (in m²); these show how much of the available floor area must be used in each version.
- Investment cost – each layout version requires different storage equipment (*e.g.*, shelf quantity, racking systems), and the estimated acquisition cost was included as an evaluation criterion.
- Workplace safety 1 – based on the position of column rows and transport routes, accident risk was an important factor.
- Workplace safety 2 – the need for and separation of buffer zones (temporary storage areas) was also evaluated. If these areas are too narrow, congestion and safety risks can occur.

Each criterion was assessed individually and used for comparison. Therefore, the decision was not based on a single index but on a multi-aspect evaluation.

Although V4 also showed favorable values, the V3 version with 4-meter aisle width delivered the shortest handling time and required fewer compromises regarding feasibility. The biggest benefit was that it balanced safety, storage space, and service speed without needing big compromises:

- Shortest total handling time (~27 hours per day), which was a primary goal to ensure fast and flexible replenishment,
- Moderate space requirement, enabling optimal use of warehouse floor area,
- Favorable rack demand, helping to control investment costs in storage equipment (Fig. 7).

Layout version	Workplace safety	Warehouse operational efficiency (work hours)	Warehouse utilization (m ²)	Investment cost (number of racks)
V1 	OK	NOK	NOK	NOK
V2 	OK	NOK	OK	OK
V3 (4 m) 	OK	OK	OK	MED
V4 	OK	OK	OK	MED

Fig. 7. Summary evaluation of warehouse layout versions (V1–V4) ((OK – favorable; MED – medium; NOK – unfavorable)

In the final decision, minimizing service time was prioritized due to the expected increase in production volume and the need for replenishment flexibility. The V3 layout with 4-meter aisle width proved to be the most balanced and feasible alternative based on these criteria. The aim of this analysis was to support the design of a new warehouse for a wood industry company using a data-driven, comparative evaluation approach. By analyzing the movement data extracted from the ERP system, classifying products, structuring the storage logic, and building a model in Excel enhanced with Visual Basic, it became possible to compare the different layout options objectively and with quantifiable results. The results highlighted that the most critical factors for warehouse performance are the length of transport paths and the positioning of dedicated storage zones and buffer areas. Previous studies on storage and retrieval systems have similarly demonstrated that travel distance and storage assignment policies significantly influence warehouse performance (Roodbergen and Vis 2009; de Koster *et al.* 2007). The study also confirmed the importance of simulation models in a dynamically changing operational environment. Beyond the findings specific to the woodworking industry, this research offers broader implications for warehouse management and strategic planning. The presented ERP-driven modeling provides a scalable and cost-effective methodology that is applicable across various industries. Since the core logic is built upon inventory movement records and spatial coordinates rather than industry-specific characteristics, the model remains highly versatile for other sectors. The robustness of the methodology is further confirmed by its subsequent application in a completely different industrial environment. Following the successful completion of the current project, the model was deployed in another industrial context, yielding similarly reliable and compelling results. By utilizing widely accessible tools such as Excel and VBA, this approach offers a viable decision-support system (DSS), enabling quantitative layout evaluations without the need for expensive simulation software.

As a next step, it is planned to link the warehouse with the production area, first by expanding the current model and later by building a Plant Simulation-based model. The project demonstrated that a widely accessible Excel-based tool, enhanced with Visual Basic coding, can effectively model warehouse movement time and capacity load. The layout alternatives were compared based on objective indicators. The chosen layout

considers handling times, space requirements, and safety aspects, supporting more efficient production servicing.

The study extends beyond the wood industry and offers a scalable solution for various industrial sectors, such as the metal industry. It can be utilized in industries where the primary challenge remains the fundamental trade-off between storage density (space utilization) and operational speed (service speed). The present ERP-based solution provides a framework for quantifying this challenge without the need for expensive simulation tools, which we will also apply in the future to support the results. Based on historical transaction data, management can identify the trade-off where aisle widths and storage technologies, on the one hand, minimize total material handling time while maintaining sustainable warehouse floor space utilization. This research proves that in industries handling unitized goods of various sizes, distance optimization based on movement frequencies is the most important tool for increasing logistical efficiency.

CONCLUSIONS

As an Excel-based static decision support tool, the model primarily focuses on long-term capacity requirements and average throughput based on historical data. It does not account for dynamic operational factors such as momentary traffic congestion or equipment-level waiting times. While these factors can be critical for short-term operational scheduling, the current approach provides a sufficient basis for strategic layout planning and the comparative evaluation of overall layout alternatives. This research aimed to optimize the layout of a new warehouse facility for a company in the wood industry by comparing four distinct layout alternatives (V1 to V4). The evaluation was based on real-world data extracted from the ERP system and measured process times to identify the most efficient configuration for storing components and parts. The compared versions ranged from a traditional racking layout (V1) and a block-stacking concept (V2) to combined systems (V3) and an optimized racking design featuring dedicated transfer zones (V4). The conclusions drawn from these comparisons are summarized below.

1. V1: The protected placement of columns ensured favorable occupational safety. Due to the large aisle widths, internal buffer zones were not required, which allowed flexible replenishment. However, this version required the largest total area and highest investment cost, and also had the longest material handling time among the four versions.
2. V2 (original block-stacking concept): The material handling time was lower than in V1 but higher than in the other two alternatives. This version showed favorable values for required space and racking needs due to the mostly block-stacked storage. However, handling block-stacked materials raised safety concerns, although the fact that this version differed less from the current operation meant that its implementation risk was relatively low.
3. V3: This version was evaluated with two aisle width configurations (3 meters and 4 meters). The model showed low material handling time and satisfactory space usage. The 3-meter aisle provided a compromise solution: the current forklifts could not operate between the racks, and some column positions overlapped with forklift paths, creating safety issues. With wider aisles (4 m), the used area increased slightly, but the current logistics equipment could be used efficiently without additional load transfers

between aisle types.

4. V4: Like V1, this version featured protected column rows, which was favorable from a safety point of view. Its overall operational efficiency was close to V3, with only a slightly higher handling time. The space utilization and racking need (300 rack positions) were also favorable. However, the limited capacity of buffer zones and horizontal layout could pose some risks.

ACKNOWLEDGEMENTS

The authors express their gratitude to the manufacturing company involved in this project, which – although chose to remain anonymous for data protection reasons – provided full access to the necessary data and significantly contributed to the success of the research through its professional collaboration.

Use of Generative AI

The authors declare that OpenAI's ChatGPT was used solely for language editing of the English text. All data, analyses, and figures are original and were created entirely by the authors.

REFERENCES CITED

- Baker, P., and Canessa, M. (2009). "Warehouse design: A structured approach," *European Journal of Operational Research* 193(2), 425-436.
<https://doi.org/10.1016/j.ejor.2007.11.045>
- Banks, J., Carson, J. S., Nelson, B. L., and Nicol, D. M. (2010). *Discrete-Event System Simulation*, 5th Ed., Pearson Education, Upper Saddle River, NJ.
- Bartholdi, J. J., and Hackman, S. T. (2019). *Warehouse & Distribution Science*, Release 0.98, Georgia Institute of Technology, Atlanta.
- Davenport, T. H. (1998). "Putting the enterprise into the enterprise system," *Harvard Business Review* 76(4), 121-131.
- de Koster, R., Le-Duc, T., and Roodbergen, K. J. (2007). "Design and control of warehouse order picking: A literature review," *European Journal of Operational Research* 182(2), 481-501. <https://doi.org/10.1016/j.ejor.2006.07.009>
- Derpich, I., Sepúlveda, J. M., Barraza, R., and Castro, F. (2022). "Warehouse optimization: Energy efficient layout and design," *Mathematics* 10(10), article 1705. <https://doi.org/10.3390/math10101705>
- Dobos, I., and Gelei, A. (2015). "Setting safety stocks based on forecasting: A case study from the practice of a pharmaceutical merchant company," *Vezetéstudomány - Budapest Management Review* 46(4), 14-22.
- Frazelle, E. (2002). *World-Class Warehousing and Material Handling*, McGraw-Hill, New York.
- Gagliardi, J. P., Renaud, J., and Ruiz, A. (2007). "A simulation model to improve warehouse operations," *Winter Simulation Conference*.
<https://doi.org/10.1109/WSC.2007.4419831>
- Gu, J., Goetschalckx, M., and McGinnis, L. F. (2010). "Research on warehouse design

- and performance evaluation: A comprehensive review,” *European Journal of Operational Research* 203(3), 539-549. <https://doi.org/10.1016/j.ejor.2009.07.031>
- Hapsari, I., Arlianto, J. A., and Santoso, P. (2025). “Simulation-based enhancement of warehouse layout and inventory control in an Indonesian pharmaceutical manufacturer,” *Jurnal Aplikasi Bisnis Dan Manajemen* 11(2), article 457. <https://doi.org/10.17358/jabm.11.2.457>
- Heragu, S. S. (2016). *Facilities Design*, 4th Ed., CRC Press, Boca Raton.
- Hofmann, E., and Rüsch, M. (2017). “Industry 4.0 and the current status as well as future prospects on logistics,” *Computers in Industry* 89, 23-34. <https://doi.org/10.1016/j.compind.2017.04.002>
- Jeon, H.-w., Ebrahimi, A., and Lee, G.-h. (2023). “A simulation-based experimental design for analyzing energy consumption and order tardiness in warehousing systems,” *Sustainability* 15, article 14891. <https://doi.org/10.3390/su152014891>
- Kelle, P., Woosley, J., and Schneider, H. (2019). “ERP systems and supply chain performance,” *International Journal of Production Research* 57(15-16), 4837-4853. <https://doi.org/10.1080/00207543.2018.1555267>
- Lu, W., McFarlane, D., Giannikas, V., and Zhang, Q. (2016). “An algorithm for dynamic order-picking in warehouse operations,” *European Journal of Operational Research*, 248(1), 107-122. <https://doi.org/10.1016/j.ejor.2015.06.074>
- Önüt, S., Tuzkaya, U. R., and Doğaç, B. (2008). “A particle swarm optimization algorithm for the multiple-level warehouse layout design problem,” *Computers and Industrial Engineering* 54(4), 783-799. <https://doi.org/10.1016/j.cie.2007.10.012>
- Petersen, C. G. (1999). “The impact of routing and storage policies on warehouse efficiency,” *International Journal of Operations & Production Management* 19(10), 1053-1064. <https://doi.org/10.1108/01443579910291043>
- Qiu, R., and Mikkonen, E. (2004). “GIS-based decision support system for wood logistics,” *Forestry Studies in China* 6(4), 29-33. <https://doi.org/10.1007/s11632-004-0027-z>
- Roodbergen, K. J., and Vis, I. F. A. (2009). “A survey of literature on automated storage and retrieval systems,” *European Journal of Operational Research* 194(2), 343-362. <https://doi.org/10.1016/j.ejor.2008.01.038>
- Roodbergen, K. J., Vis, I. F. A., and Taylor, G. D. (2015). “Simultaneous determination of warehouse layout and control policies,” *International Journal of Production Research* 53(11), 3300-3314. <https://doi.org/10.1080/00207543.2014.978029>
- Rouwenhorst, B., Reuter, B., Stockrahm, V., van Houtum, G. J., Mantel, R. J., and Zijm, W. H. M. (2000). “Warehouse design and control: Framework and literature review,” *European Journal of Operational Research* 122(3), 515-533. [https://doi.org/10.1016/S0377-2217\(99\)00020-X](https://doi.org/10.1016/S0377-2217(99)00020-X)
- Sharer, E., Rajagopalan, H. K., and Mayadunne, S. (2022). “Building decision support systems in Excel for production and distribution planning: A case study,” *Journal of Applied Business and Economics* 24(2), article 5142. <https://doi.org/10.33423/jabe.v24i2.5142>
- Tompkins, J. A., White, J. A., Bozer, Y. A., and Tanchoco, J. M. A. (2010). *Facilities Planning*, 4th Ed., Wiley, Hoboken.
- Vieira, G. E., Dias, L. S., Pereira, G. A. B., Oliveira, J. A., Carvalho, S. M., and Martins, P. (2015). “Using Simio to automatically create 3D warehouses and compare different storage strategies,” *Proceedings of the 2015 Winter Simulation Conference*

335-343. <https://doi.org/10.5937/fmet1504335v>

Wang, Y., Gunasekaran, A., Ngai, E. W. T., and Papadopoulos, T. (2016). “Big data analytics in logistics and supply chain management,” *International Journal of Production Economics* 176, 98-110. <https://doi.org/10.1016/j.ijpe.2016.03.014>

Zhou, L., Liu, H., Zhao, J., Wang, F., and Yang, J. (2022). “Performance analysis of picking routing strategies in the leaf layout warehouse,” *Mathematics* 10(17), article 3149. <https://doi.org/10.3390/math10173149>

Article submitted: October 12, 2025; Peer review completed: March 21, 2026; Revised version received: April 30, 2026; Accepted: May 2, 2026; Published: June 12, 2026.
DOI: 10.15376/biores.21.3.6924-6942