# DYNAMIC MULTI-CRITERIA DECISION SUPPORT SYSTEM FOR DISTRIBUTION WAREHOUSE MANAGEMENT IN METALLURGICAL ENTERPRISE

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**Abstract**

In the current business environment, characterised by globalisation and technological advances, metallurgical companies are facing unprecedented challenges. In order to maintain competitiveness, these companies must demonstrate a capacity to respond to these emerging trends. In the context of intensifying competition and the pressure to reduce costs, the pursuit of innovative solutions to optimise logistics process is necessary. The implementation of advanced decision support systems supports the pivotal role of innovation and technological progress in ensuring sustained competitiveness in the metallurgical industry. The aim of paper is to present a methodology for the development of a dynamic multi-criteria decision support system for the management of distribution warehouses in the metallurgical industry in order to optimise storage, picking and loading processes. The methodology is based on a comprehensive process analysis of the warehouse management system and the identification of key factors influencing the decision-making processes. The development of a system utilizes the multi-criteria decision-making method of Analytic Hierarchy Process (AHP), with the objective of evaluating and recommending optimal storage locations based on a selection of criteria. These criteria encompass trade-offs between production, logistics and warehouse requirements, including distance from critical points and warehouse location. The proposed model was tested on selected warehouse events under defined conditions, which demonstrated its potential to significantly improve the efficiency of the distribution warehouse management system, thus increasing the competitiveness in the metallurgical industry. The proposed methodology for both process analysis and decision support system design has been generalized for wider use across the metallurgical industry.

**Keywords:** Warehouse management; multi-criteria decision making; distribution warehouse, AHP; process analysis

## 1. INTRODUCTION

The metallurgical industry operates under conditions of high material intensity, strict production continuity requirements, and increasing pressure to optimise logistics processes. Distribution warehouse management must address challenges related to handling large and heavy products, high inventory volumes, and limited flexibility in physical infrastructure. Despite logistics' critical role in operational efficiency, warehouse management systems in metallurgical enterprises remain underdeveloped, exhibiting low digitalisation and limited decision automation. Existing warehouse management research predominantly targets static improvements such as storage layout optimisation, picking strategies, and throughput enhancement. These approaches insufficiently support dynamic decision-making or adaptation to evolving warehouse conditions. Furthermore, the metallurgical sector is underrepresented in logistics research, particularly concerning integrated decision-support methodologies for warehouse operations. This study proposes a methodology for developing a dynamic multi-criteria decision support system (DSS) for storage location selection in metallurgical distribution warehouses. The methodology is grounded in detailed process analysis and identification of key decision factors. The decision model employs the Analytic Hierarchy Process (AHP) to evaluate storage location alternatives across operational, spatial, and logistical criteria. The aim is to provide warehouse management with a data-driven tool to enhance storage, picking, and loading efficiency. The paper details model development, validation through selected warehouse scenarios, and generalisation potential across similar industrial contexts.

## 2. LITERATURE REVIEW

### 2.1. Warehouse management and storage location selection

Effective storage location selection is critical in warehouse logistics as it directly impacts operational efficiency and costs. The core problem, known as the Storage Location Assignment Problem (SLAP), is NP-hard and involves optimally assigning products to storage locations. Common policies include random, dedicated, and class-based storage assignments. Advanced solutions employ heuristic and metaheuristic algorithms, such as dynamic programming and multi-stage heuristics, to reduce travel distances and improve order picking efficiency [1, 2]. Recent approaches integrate simulation and IT tools to enhance SLAP. For example, within-aisle storage combined with metaheuristic batching has shown measurable gains in picking performance [3]. Information-driven strategies like the cube-per-order index (COI) and full-turnover storage prioritize frequently accessed items in accessible locations, reducing retrieval times [4]. Storage decisions depend on operational, spatial, and product-specific factors, including space utilization, cycle time, and resource constraints. Warehouse layout and storage policy strongly influence these factors. Product attributes such as popularity and turnover are crucial; popularity-based policies position frequently picked items in prime locations to minimize travel [2]. The interplay between storage assignment and routing also matters, with turnover-based strategies placing high-turnover items near warehouse peripheries to improve picking efficiency [3, 5]. Although multi-criteria decision-making (MCDM) methods like AHP, TOPSIS, and ELECTRE are widely applied for strategic warehouse location selection, their use for internal storage decisions is limited [6]. However, integrating MCDM within Warehouse Management Systems (WMS) shows promise by enabling balanced, multi-criteria evaluations [7, 8]. Simultaneous consideration of order picking and routing benefits from MCDM, improving efficiency and accuracy [3]. Future research should prioritize integrated frameworks combining MCDM with WMS to support dynamic, data-driven warehouse decisions [9]. Strategic warehouse location decisions require long-term investments and multi-criteria assessment to balance cost, capacity, and service [6].

### 2.2. Process Mapping and Analysis in Warehouse Management

Understanding internal warehouse operations is essential for effective management, achievable through systematic process mapping and analysis. These tools identify inefficiencies, optimize resource allocation, and align operations with strategic goals [10]. Process maps visually represent workflows, aiding resource allocation decisions across reception, storage, picking, and dispatch. They also support evaluation of critical metrics like travel distance and processing time [8]. Detailed process maps align warehouse logistics with broader distribution strategies and enable integration of interconnected planning problems, enhancing overall optimization [5]. Process analysis complements mapping by evaluating warehouse operations comprehensively. It identifies inefficiencies and supports improvements in inventory management and order fulfillment, central to performance [7]. Analytical evaluation assists managers in allocating space, labor, and equipment efficiently, meeting operational requirements at minimal cost [10]. It also facilitates performance assessment through metrics like storage capacity and space utilization and enables dynamic, multi-objective problem-solving with responsive strategies [9].

## 3. PROBLEM DEFINITION

Scientific literature on warehouse and distribution management in manufacturing primarily addresses static improvements such as picking, storage, layout design, and waste reduction. However, dynamic approaches enabling flexible adaptation to changing warehouse conditions and evolving customer demands remain limited, particularly in the metallurgical industry, where warehouse-focused research is scarce. Warehouse management in metallurgy is characterised by handling large, heavy materials and maintaining substantial safety stocks to ensure continuous production, resulting in significant capital tied up in inventories and high storage costs. The sector also suffers from low digitalisation; information systems are often outdated or fragmented, partly due to long equipment lifespans and investments prioritised for environmental compliance rather than process innovation. This environment creates a clear need for flexible, data-driven decision support systems capable of adapting warehouse operations dynamically. This study proposes such a system based on detailed process analysis and the Analytic Hierarchy Process (AHP), aiming to optimise storage location decisions by balancing production, logistics, and spatial constraints. Validation on selected scenarios demonstrates the system's potential to enhance warehouse efficiency and competitiveness in the metallurgical sector. [11].

## 4. METHODOLOGY OF PROCESS ANALYSIS OF LOGISTICS IN THE DISTRIBUTION WAREHOUSE OF A METALLURGICAL COMPANY

The proposed methodological framework supports the analysis of warehousing and distribution processes, including their management, to generate input data for a dynamic decision support system in a metallurgical warehouse context. The procedure is structured into sequential steps detailing activities, applied methods, required inputs, and expected outputs. This process is documented through a textual description linked to the block diagram in Figure 1, where each numbered step corresponds to key activities and sub-activities, with defined inputs and outputs forming the analytical structure.

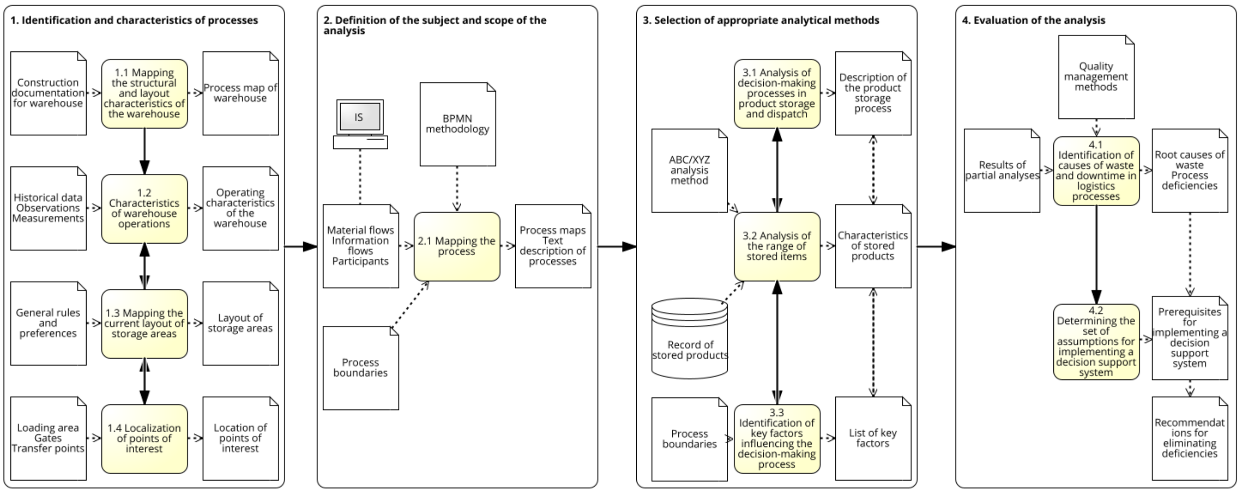


**Figure 1** Block diagram of the methodology for process analysis of logistics in the dispatch warehouse of a metallurgical company

**1. Identification and Characterization of Processes:** This initial step involves identifying and describing all relevant warehouse processes at an appropriate level of detail.

**1.1 Mapping Structural and Layout Characteristics:** The warehouse layout is mapped using construction and operational documents, supplemented by on-site observations, measurements, and staff interviews to produce an accurate operational map for further analysis.

**1.2 Operational Characteristics:** Key operational parameters are defined concurrently, including storage capacities, handling methods and equipment specifications, personnel roles and schedules, transport means, and shipment volumes based on historical data and observations.

**1.3 Mapping Storage Areas:** Storage zones are identified and described by their physical attributes, operational procedures, and allocation rules, with diagrams integrated into the warehouse map using warehouse management system data.

**1.4 Localization of Points of Interest:** Critical points such as loading zones, gates, equipment, and transfer stations are identified and mapped alongside movement routes of materials, personnel, and vehicles, including their position, capacity, and dimensions.

**2. Definition of Subject and Scope of Analysis:** The boundaries of the logistics process analysis are established, defining the processes under investigation and their interactions with related activities, particularly production, with all relevant assumptions and constraints documented as defined by the process owner.

**2.1 Process Mapping:** Using BPMN methodology and software, storage and distribution processes are mapped from order creation to shipment, capturing subprocesses, decision nodes, information flows, systems, documentation, and participant roles. Hierarchical subprocess mapping allows detailed analysis of key operations such as storage and loading.

**3. Selection of Appropriate Analytical Methods:** Suitable analytical methods tailored to the warehouse context are selected, with recommendations on data collection, recording, and interpretation techniques.

**3.1 Analysis of Decision-Making Processes:** Critical decision points, especially storage location assignment, are analyzed by detailing objectives, criteria, responsible personnel, and workflows, supported by decision maps or flowcharts.

**3.2 Analysis of Stored Items:** A comprehensive dataset of stored and shipped products is created from warehouse records, including dimensions, turnover, production volume, shipment type, and quality, classified via ABC/XYZ methods to support modeling.

**3.3 Identification of Key Decision Factors:** Using quality management tools (Ishikawa diagrams, Pareto analysis, histograms) and stakeholder workshops, key factors influencing decisions are identified, prioritized, and categorized into:

- General preferences (rules, warehouse constraints, customer needs)
- Product characteristics (dimensions, weight, quality)
- Storage location attributes (size, position, capacity)
- Warehouse status (available space, handling and personnel capacity)

**4. Evaluation of the Analysis:** Results from all sub-analyses are consolidated into structured documentation to inform decision support model development.

**4.1 Identification of Waste and Downtime Causes:** Quality tools are used to identify inefficiencies such as layout constraints, poor information flow, suboptimal planning, inadequate system integration, and inventory inaccuracies, highlighting barriers to DSS implementation.

**4.2 Determination of Prerequisites for DSS Implementation:** Based on identified shortcomings, actionable prerequisites are defined to achieve the target logistics system, including:

- Availability of necessary information to staff
- Established methodologies for product storage
- Designed decision-making processes for storage location selection
- Developed methodologies for layout redesign
- Visualization tools for warehouse status

## 5. METHODOLOGY FOR DEVELOPING A DECISION SUPPORT SYSTEM MODEL FOR STORING PRODUCTS IN THE DISPATCH WAREHOUSE OF A METALLURGICAL COMPANY

This chapter outlines a general methodology for constructing a decision support system model for managing a dispatch warehouse in a metallurgical company, based on outputs from the preceding process analysis. Core inputs include warehouse, storage, and product characteristics, a defined decision-making process, and key influencing factors. The procedural framework is presented as a textual description linked to the block diagram in Figure 2, which parallels the structure of the previous chapter's diagram.

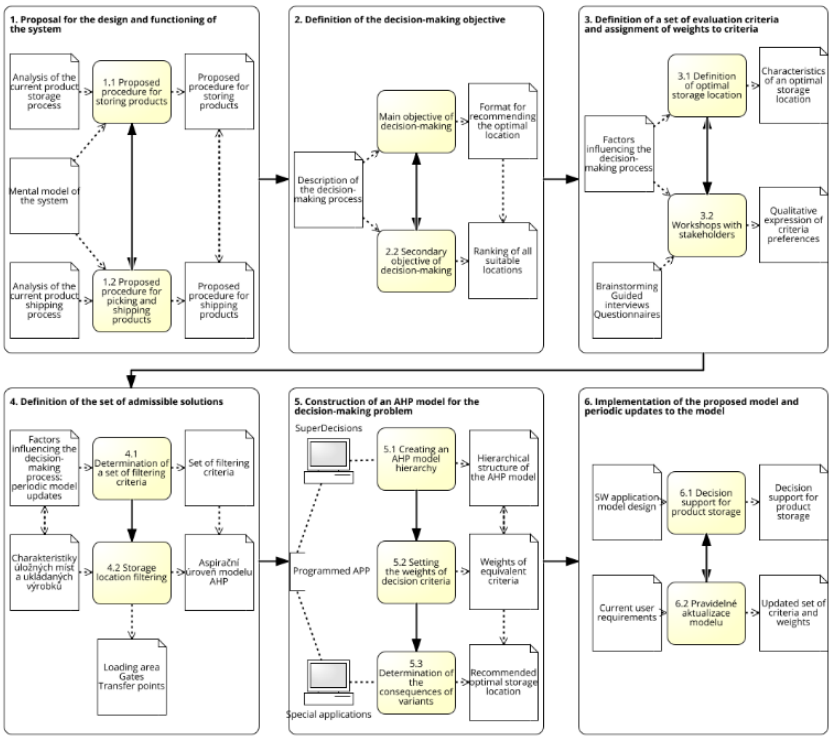


**Figure 2** Block diagram of the methodology for creating a decision support system model for storing products in the dispatch warehouse of a metallurgical company

**1. Design of the System's Form and Functioning:** Development begins by defining the target structure and operation of the product storage process and decision-making workflow, using a mental model to envision the future system and guide redesign of storage activities.

**1.1 Proposed Procedure for Product Storage:** The storage process is reconfigured to incorporate interactions with dispatch planning, picking, and distribution, embedding decision support functions within revised physical and information flows. Roles, responsibilities, and inputs/outputs are clearly defined and documented, often supported by process maps.

**1.2 Proposed Procedure for Picking and Distribution:** Concurrent with storage redesign, picking and distribution procedures are defined, detailing activity sequences, inputs, outputs, and staff roles, and documented descriptively with optional process visualization.

**2. Definition of the Decision-Making Objective:** Based on prior process analysis, the system's primary objective is defined: to recommend optimal storage locations that improve storage and distribution efficiency.

**2.1 Main Decision-Making Objective:** The model generates recommendations for optimal storage locations tailored to current operational data, presented to warehouse managers who may accept or override them. The output format is specified.

**2.2 Secondary Objective:** A secondary function ranks all suitable storage locations, providing alternative options if the primary recommendation is unavailable due to unmodeled constraints.

**3. Definition of Evaluation Criteria and Assignment of Weights:** Evaluation criteria are selected based on process analysis and their impact on efficiency. Criteria weights are assigned using Saaty's pairwise comparison method during stakeholder workshops.

**3.1 Definition of Optimal Storage Location:** Characteristics defining optimal storage locations for all product types are established to guide evaluation.

**3.2 Workshops with Stakeholders:** Workshops involving logistics, production, sales, customers, and carriers employ brainstorming, interviews, and questionnaires to derive qualitative criterion relationships, which are quantitatively expressed via Saaty's scale.

**4. Definition of Acceptable Solutions:** Filtering criteria eliminate unsuitable storage locations before detailed evaluation, creating a refined set of candidates.

**4.1 Determination of Filtering Criteria:** Non-critical decision factors serve to identify potentially suitable storage locations.

**4.2 Filtering of Storage Locations:** Storage location attributes are compared with product and warehouse characteristics to filter and identify acceptable locations.

**5. Construction of the AHP Model:** The AHP model ranks acceptable storage locations based on distance criteria derived from process analysis.

**5.1 Hierarchical Structure Creation:** A three-level hierarchy is constructed:

Level 1: Decision goal (optimal storage location)

Level 2: Evaluation criteria (distances from points of interest)

Level 3: Decision alternatives (acceptable locations)

**5.2 Setting Criteria Weights:** Criteria weights from stakeholder workshops are incorporated into the model.

**5.3 Determining Variant Consequences:** Distances from each storage location to points of interest are calculated, and the model produces an optimal location recommendation alongside a ranked list of alternatives.

**6. Implementation and Periodic Updating**

**6.1 Implementation:** The model supports iterative evolution, allowing changes to structure and criteria weights in response to operational needs.

**6.2 Periodic Updates:** User-led updates and increasing reliance on model recommendations improve decision quality and warehouse efficiency over time.

## 6. CONCLUSION

The present paper sets out a methodology for the development of a dynamic decision support system with the aim of improving the management of distribution warehouses in the metallurgical industry. The system is predicated on a structured process analysis and employs the AHP method to evaluate and prioritise storage locations based on predefined criteria related to logistics, production, and spatial configuration. The proposed methodology consists of two main components: process analysis to identify warehouse-specific operational characteristics and decision factors, and model development to support dynamic and criteria-based decision-making. The resulting system facilitates the recommendation and ranking of suitable storage locations, thereby enabling operational flexibility and higher process efficiency. The experimental model was subjected to rigorous scrutiny under strictly defined conditions. This rigorous testing process confirmed the applicability of the methodology and demonstrated significant improvements in the speed and quality of storage-related decisions. The integration of stakeholder input and structured evaluation criteria has been demonstrated to increase decision transparency and support alignment with operational objectives. The findings suggest that the implementation of the proposed system could contribute to the reduction of warehouse inefficiencies, the improvement of space utilisation, and the enhancement of responsiveness to logistical constraints. The methodology can be adapted to other material-intensive industries that exhibit similar operational characteristics, and future research should concentrate on real-time data integration and broader deployment within warehouse management systems.

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