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ANALYSIS OF INVENTORY MANAGEMENT ISSUES IN WAREHOUSE LOGISTICS OF MANUFACTURING ENTERPRISES BASED ON A SYSTEMATIC APPROACH

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Introduction

The role of warehouse logistics in modern manufacturing enterprises extends beyond material storage. Warehouses have become a strategic element of the supply chain. They play a decisive role in ensuring production continuity, improving service levels, and optimising overall logistics costs. In this context, the proper formation and management of reserves are key to the enterprise's economic sustainability.

Since warehouse processes are characterized by uncertainty, variable demand, resource constraints, and internal bottlenecks, mass service systems (MSS) and discrete-event simulation models, especially the GPSS World (General purpose simulation system World) modeling system, act as effective scientific and practical tools in their analysis.

The article examines the economic essence of warehouse logistics in manufacturing enterprises, analyses the concepts and types of reserves, the functions of reserve management systems, the factors affecting reserve levels, and the shortcomings of existing systems.

The economic essence of warehouse logistics in manufacturing enterprises

The economic essence of warehouse logistics in manufacturing is balancing two goals: ensuring production continuity by creating a “stop” in the material flow, and minimising the associated costs. The warehouse is more than just storage; it is where the product temporarily pauses in the supply chain. This uses both space and time resources, generating economic costs [1,5,6]. Thus, the warehouse’s economic role is to balance service levels (stock availability, timely delivery) with total logistics costs (storage, operations, losses, delays).

To clarify the reasoning for the compromise, the MSS logic is applied. In a production warehouse, the workflow (reception → control → placement → order picking → release) can be modelled as “application flows” and “service channels.” For instance, truck arrivals in the receiving zone are random, with the receiving brigade acting as the “serviceman,” resulting in queues, waiting times, reduced throughput, and traffic jams. Mass service theory (MST) formalises queue lengths, waiting times, channel occupancy, and intensity conditions for system stability [1,2], with average queue length, average waiting time, and channel occupancy as key indicators. The warehouse’s economic performance can be described using these MST metrics and cost units. For example, longer waiting times increase the risk of production downtime, and traffic jams raise operating costs and lower service levels.

Economic results are not purely analytical, as real-world processes introduce factors such as priorities, nonlinear routes, variable service times, resource sharing, and parallel flows. At this point, discrete-event simulation environments such as GPSS World are valuable. In GPSS World, processes are modelled as “flows of objects,” and simulation elements such as material batches or orders are represented as transactions that compete for resources and are queued as necessary [3,4,5]. This enables a comprehensive economic analysis of warehouse logistics.

For example, increasing the number of channels (servers) at the warehouse entrance reduces waiting time but raises economic costs. This classic “capacity and waiting” dilemma also appears in MSS and simulation models. In the queue approach, analytical results show the general direction of change. Still, in complex systems, simulation can clarify specific operational impacts (such as those from priority, batch, or return methods) [1]. Some authors note that “simple rule-coefficients” based solely on experience are insufficient to optimise warehouse operations; they recommend adjusting these rules using real order data and mathematical or computer models [5,6]. This focus does not change the economic fundamentals of warehouse logistics; rather, it allows costs and service metrics to be measured together in a unified model.

Studies show that, as a result, the economic essence of warehouse logistics in a manufacturing enterprise is based on three pillars:

- stabilising the flow of materials and reducing production downtime (service level);
- managing inventory and operating costs (transportation, storage, losses);
- resource loading and queueing optimisation (MSS + simulation). To translate this trio into practical decisions, a process-interaction simulation language such as GPSS World allows us to determine and compare the “economic behaviour” of a warehouse in different scenarios [3,4].

Classification of reserve types

The concept of reserves functions as a “buffer,” absorbing uncertainties in production and warehouse logistics. This stabilises material flows and supports service levels by reducing process downtime. However, reserves also incur economic penalties, such as tying up capital, storage costs, risks of obsolescence, and potential loss. Thus, accurate selection and classification of reserve types are crucial for planning and control. Studies underscore that these steps are key to effective operations.

One direction of the classical classification divides reserves according to their function:

- periodic reserve;
- safety reserve;
- transit reserve;
- seasonal reserve, etc.

Another widely used approach is the classification according to the type of demand:

- independent demand reserve;
- dependent demand reserve.

Some sources emphasise that this classification radically changes the logic of software and planning. In a distribution environment, purchases of finished goods and spare parts are based on historical usage and consumption patterns. In contrast, in manufacturing, purchases of raw materials and semi-finished products are driven by the master production schedule and the bill of materials. These distinct approaches are discussed separately in the context of inventory types [7,8]. This means two different management philosophies can exist under the same warehouse.

From a warehouse perspective, inventory is the material equivalent of a “waiting line” in a queuing system. Since requests (e.g., orders, production requirements) arrive randomly in the system, service resources (machines, workers, lifting equipment) may not be available in sufficient numbers, leading to a queue. Queue formation has two outcomes: either the customer waits (service is delayed), or the system reserves inventory in advance to create a “ready state”. In a warehouse, performance indicators (waiting time, system dwell time, etc.) help explain the service level results of the inventory policy [1,2]. Thus, the classification of inventory types is also carried out according to what uncertainty (demand variability, supply delays, production variability, internal bottlenecks) they actually compensate for. The practical side of classification is more evident in warehouse operations. It should be noted that warehouse decisions (e.g., area allocation, placement strategy) should be based on models that account for each product unit's behaviour and economic value, which are tracked separately in the warehouse or inventory system. The inventory level changes over time as a function of input and output flows; i.e., inventory has a "flow behaviour" rather than "just a number" [5,6]. Part of this behaviour is shaped by the frequency of demand, batch size, and service requirements of the product unit, which brings to the fore classifications such as ABC/VEN (group A - high-value, small-numbered, products requiring strict control, group B - medium-value products, group C - low-value, numerous products/ V (Vital) - products whose absence causes a process stoppage, E (Essential) - products that have alternatives but are important, N (Non-essential) - products that are easy to replace). This classification is a combined analysis method that ensures the management of resources across both economic and criticality levels. Some sources also indicate that the ABC and VEN approaches are useful for selecting resources and determining which items to keep in stock [9,10]. Such classifications serve a prioritisation function in resource management under resource limitations. In the context of GPSS World, inventory type classification becomes part of the model. Transactions (order, material batch) can be defined as different classes, priority, route, and service time distributions are differentiated according to the type of inventory. In the GPSS World approach, the simultaneous "movement within the model" of transactions with multiple flows enables the simulation of parallel operations in a real warehouse [3,4]. For example, the safety stock policy is built into the model as a reorder point rule. In the seasonal inventory scenario, the intensity of incoming demand varies over time, leading to changes in queue service levels. This shows that the inventory classification is not just a term, but a set of decision parameters.

In conclusion, let us note that the concept of inventory is not limited to "storage"; it is a mechanism for managing uncertainties. The classification of inventory types serves to identify the source of that uncertainty and select an appropriate control policy, dependent vs independent demand, selection and prioritisation (ABC/VEN), optimisation of warehouse behaviour [5-10] is given. The issue of evaluating the actual outcomes of these policies using MSS indicators and GPSS World simulation is discussed in [1,2].

Determining the main functions of inventory management systems

The inventory management system should answer questions about when and how much to order at the enterprise level, as well as the level of service to be provided. The answer to these questions is not only a mathematical model but also the organisation of the information-collection, processing, decision-making, and control cycle. Therefore, the functions of the system can be grouped into four blocks:

- information and accounting;
- planning and forecasting;
- execution and operational control;
- performance evaluation and comparison, improvement.

Studies show that in technical literature, the main issues for effective inventory management (accounting records and reports, safety (insurance) reserves, when and how much to order, cost control) are listed sequentially, emphasising that the system differs depending on the context (dependent demand production vs independent demand distribution) [9-11].

From the point of view of MSS, the functions of the inventory management system serve the "stability of flows". If the order flow is random and service resources are limited, then the system either creates a wait (queue) or tries to reduce the wait by keeping a reserve. Based on the MST performance indicators (waiting, occupancy, throughput), the “service level” efficiency is defined [1,2]. Therefore, after the “service level” target is selected in the inventory management system, the safety margin, reorder interval, etc., are adjusted accordingly. This [9,10] The source clearly shows that the safety margin is the main indicator of service level and that the cost of maintaining an excessive safety margin increases.

One of the most critical functions of the system at the implementation level is to maintain the correspondence between the “actual reserve” and the “paper reserve”. Here, that is, [7,8] explains that in real-time systems, inventory is immediately “reserved for order” when a picking document is created, and notes that if there is a time lag between documentation and actual shelf arrival, users’ trust in inventory records is weakened. As a result, items reserved for other orders can be “unauthorised.” This description suggests that the function of an inventory management system is not only “calculation” but also affects organisational behaviour.

The GPSS World approach is useful at two levels here. The first level is to simulate the impact of inventory management rules (e.g., min–max, periodic review) on operational flows. The second level is to model the behaviour of the information system (real-time and batch processing, delayed updates, electronic read errors) as “events” in the process flow. In GPSS World, transactions compete for resources and automatically queue, and the interaction of parallel processes is suitable for simulating the real behaviour of a warehouse/production environment [3,4]. For example, the delay of the “replenishment” event can be modelled as a separate block, and congestion in the order-picking area and order delays can be measured. The financial equivalent of this delay (penalty, delay cost, lost sales) is calculated.

Studies have shown that the main functions of inventory management systems can be summarised as follows [1-4,7-10]:

- Accounting and transparency. Real inventory, allocated inventory, transit inventory, rapid inventory counting and detection of discrepancies [7,8].
- Planning. Selection of the method according to the nature of the demand (dependent or independent demand) [7,8], reorder policy [9-11].
- Service level and risk management. Safety margin, variability of the time of execution of the operation, and the effect of congestion [9-11].
- Performance evaluation. Service level, inventory, holding and ordering costs. Operational delay assessment with MSS indicators [1,2].
- Improvement with simulation. “Policy + process” is tested in a GPSS World model [3,4].

Analysis of factors influencing the formation of inventory levels in warehouse logistics

Inventory levels are not “just a plan figure”, but the result of numerous interrelated factors. These factors can be grouped as follows:
- demand side;
- supply side;
- internal operational side;
- information/management side.

Demand-side factors include average demand levels, demand variability, seasonality, campaigns, and the unique product unit mix. When demand is variable, the safety margin increases to maintain the service level [9-11] shows that the safety margin is directly related to the service level and that both consumption and time variations from the start to the end of an operation, order, or production process should be taken into account, [5,6], it is emphasized that the real order history (what and when was ordered) can be used to adjust warehouse operations, which enhances the differentiation of inventory levels according to the unique behaviour of the product unit.

Supply-side factors include lead time (the time from start to finish of an operation, order, or production process), its variance, minimum lot size, supplier reliability, and shipping delays. As the time from start to end of an operation, order, or production process increases, the reorder point increases; as variability increases, the safety margin increases. Although these effects are classical inventory logic, their connection to the SCM is that the internal "service system" of the warehouse/production can also create congestion during the start-to-finish of an operation, order, or production process. That is, not only the supplier, but also the company's own internal processes create "waiting".

Internal operational factors include receiving, placing, order picking, the power of picking resources, the capacity of the passages, the equipment fleet, the staff schedule, technical downtime, and quality checks. The MSS works most clearly in this part: as the intensity of the request approaches that of the service, queues grow rapidly, and time spent in the system increases [1,2]. This increase affects the inventory level in two ways:

- the execution of orders is delayed, which means that the pressure to "keep more inventory" arises;
- congestion disrupts the balance of inventory by location (for example, a shortage in the order picking zone, excess inventory in the back zone), and [5,6] emphasises that the warehouse is a point where "the product is touched and paused", which is precisely these internal operational costs and time losses.

Information and management factors include the accuracy of inventory records, system update delays, real-time batch, user discipline, and integration problems. In real-time systems, the time lag between document life and physical movement disrupts the ability to track the current quantity, location, and status of inventory in the warehouse or in the system. It can negatively influence employee behaviour [7,8]. Such "invisible" factors often lead to inflated inventory levels, and managers often require more inventory "for insurance" when they do not trust records.

Although each of these factors affects its own, in a real system, their interactions are key. For example, the time variability of customer demand, combined with limited storage capacity, results in order delays, which the manager interprets as "low inventory" and increases inventory, leading the warehouse to fill up and the operation to become more difficult. This is a classic "feedback loop" and is difficult to solve analytically. Here, GPSS World simulation is a powerful method, processes are built in parallel, transactions compete for resources, and bottlenecks are automatically created [3,4]. Then the stock policy (reorder point and batch size) is changed, and the performance indicators are compared.

Let's look at a practical conceptual scheme in GPSS World.

- Transaction = "order" (or "material request")
- Facilities/Resources = motorised equipment designed to remove, collect, transport and place items and products from the shelf, receiving brigade, order picking worker
- Queue/Depart = queue entry and exit
- Seize/Release = resource seizure and release

Note that this structure corresponds to the GPSS World process-interaction model's logic and facilitates the identification of bottlenecks [3,4].

Thus, the research and practical experience show that the factors influencing stock level formation are not only demand and supply but also the behaviour of the internal service system (ISIS). Queue indicators [1,2], the principles of reserve policy [9-11], and the GPSS World simulation [3,4] should be used together.

Analysis of existing inventory management systems and their shortcomings

Although existing inventory management systems (reserve modules of enterprise resource planning systems, warehouse management systems, special programs) have become very functionally rich, in practice, shortcomings are usually revealed at three levels:

- model and reality mismatch;
- data quality and integration problems;

- human factor and process discipline.

Regarding the issue of model and reality mismatch, it should be noted that many systems are based on standard policies (min-max, economic order batch used in inventory management, periodic review). These policies are useful, but in the real-world warehouse process, factors such as service times, priorities, resource sharing, critical points where the process slows down, and underutilised resources are not "fixed parameters". MSS shows that as resource loading increases, the waiting time can grow sharply, and small changes can cause large delays [1,2]. If the system does not take this into account, for example, a traffic jam in the order picking area can be misinterpreted as "stock shortage", and management will tend to overstock.

As for data and integration problems, in addition to the difficulty of integration when different branches use different software and one is distribution-oriented, and the other is production-oriented, problems arise when the sequence and timing of information flow are not precisely established in advance [7,8]. This is a typical shortcoming seen in many enterprises. To manage operations in production and logistics systems in a unified and efficient manner, the integration of software systems creates a situation where the master data stored in the system does not match each other or with the operational data (the situation where the master data stored in the system does not match each other or with the operational data) and causes delayed synchronisation.

In the case of human factors and process discipline, it is explained that when a product appears on paper as a "reserved stock", it is unavailable in the real-time system. However, it is still physically on the shelf; when employees do not understand this, trust in the records decreases, and the risk of the reserved products being "unauthorised used stock" increases [7,8]. This is not just a technical issue but a combined deficiency in the system's structure, training, and process discipline.

Research has shown that the "analysis" process can be strengthened to overcome these shortcomings by the following two means:

1. Analysis of the MSS. Questions such as where the process slows down, where resources are underutilised, what the resource occupancy and waiting times are, and whether the system is in a stable mode arise. In this case, the MSS performance indicators (average time spent by the request in the queue and in the system, average value of the queue length, average number of requests in the system, intensity brought, etc.) help to reveal the cause and effect of traffic jams [1,2].

2. GPSS World simulation (policy testing). Since real processes operate in parallel and interact, simulation models the "system behaviour" in a scenario. In GPSS World, automatic transaction queuing based on resources and the natural model structure of parallel processes facilitates analysis even in complex systems [3,4]. This is especially useful for showing why options for an existing system that look "good on paper" do not work in practice.

The problems of relying on simple rules in warehouse practice are highlighted in [5,6], and the optimisation of operations is discussed using mathematical and computer models. This idea holds for the analysis of existing storage systems: the system is not just a "calculator"; it is part of the process, and if the process is congested, the system output is also distorted.

In conclusion, we can note that the main shortcomings of existing reserve management systems are:

- Poor modelling of the impact of process bottlenecks (queues) on reserve decisions [1,2].
- Inconsistency in timing and integration of information flow [7,8].
- Paradoxes and user behaviour risks caused by real-time monitoring [7-9].
- Inconsistency of the "rule-coefficient" approach with real operational dynamics [5,6].

To translate these problems into practical decisions, diagnostics with MSS indicators and scenario tests with GPSS World simulation should be applied together [3,4].

Conclusions

The analysis shows that inventory management in warehouse logistics in manufacturing enterprises is not limited to inventory calculations alone. These processes operate as service systems and are closely related to queues, congestion, and resource loading. Thus, MSS provides analytical diagnostics of warehouse operations, while GPSS World simulation models the dynamic behaviour of real processes and creates conditions for optimal decision-making.

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ANALYSIS OF INVENTORY MANAGEMENT ISSUES IN WAREHOUSE LOGISTICS OF MANUFACTURING ENTERPRISES BASED ON A SYSTEMATIC APPROACH

The article examines inventory management in warehouse logistics for manufacturers using a systematic approach. It analyses the warehouse's economic role, showing it is more than storage; it supports production, improves service, and impacts logistics costs. The article also distinguishes between independent and dependent demand inventories, outlining their roles in managing recurring, safety, transit, and seasonal stock.

The article explains in detail the main functions of inventory management systems: accounting and data collection, planning and forecasting, order fulfilment, operational control, and performance evaluation. It also analyses specific factors affecting inventory levels in warehouse logistics: demand variability, supply time, internal operational capacity, resource constraints, and the quality of information systems.

The study uses mass service systems (MSS) and GPSS World (General Purpose Simulation System World) discrete-event simulation as its methodological foundation. By combining GPSS simulation with the analytical MSS approach, the study identifies shortcomings in inventory management systems. This integration optimises inventory levels and improves warehouse logistics efficiency within manufacturing enterprises.

Key words*: warehouse logistics management, inventory management, mass service systems, mass service theory, GPSS World simulation, production logistics.*

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АНАЛІЗ ПРОБЛЕМ УПРАВЛІННЯ ЗАПАСАМИ У СКЛАДСЬКІЙ ЛОГІСТИЦІ ВИРОБНИЧИХ ПІДПРИЄМСТВ НА ОСНОВІ СИСТЕМНОГО ПІДХОДУ

У статті розглядається управління запасами у складській логістиці для виробників з використанням системного підходу. У ній аналізується економічна роль складу, показуючи, що він – це більше, ніж просто зберігання; він підтримує виробництво, покращує обслуговування та впливає на логістичні витрати. У статті також розрізняються запаси незалежного та залежного попиту, окреслюючи їхню роль в управлінні періодичними, безпечними, транзитними та сезонними запасами.

У статті детально пояснюються основні функції систем управління запасами: облік та збір даних, планування та прогнозування, виконання замовлень, операційний контроль та оцінка ефективності. Також аналізуються специфічні фактори, що впливають на рівень запасів у складській логістиці: мінливість попиту, час постачання, внутрішні операційні можливості, обмеження ресурсів та якість інформаційних систем.

У дослідженні як методологічну основу використовуються системи масового обслуговування (СМО) та дискретно-подієве моделювання GPSS World (General Purpose Simulation System World). Поєднуючи моделювання GPSS з аналітичним підходом СМО, дослідження виявляє недоліки в системах управління запасами. Така інтеграція оптимізує рівні запасів та підвищує ефективність складської логістики на виробничих підприємствах.

Ключові слова: *управління складською логістикою, управління запасами, системи масового обслуговування, теорія масового обслуговування, моделювання GPSS World, виробнича логістика.*

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