Supply Chain Optimization and Working Capital Requirement Management: literature review

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Abstract. Effective supply chain management (SCM) minimizes expenses while maintaining material flow balance. This paper highlights the lack of Working Capital Requirement (WCR), a crucial metric for evaluating organizational liquidity and financial stability, in Supply Chain Optimization despite research indicating only a weak correlation between SCM and financial performance. The review covers a selection of papers found using predetermined SCM and WCR related search criteria in large academic databases.

Keywords: Supply Chain Optimization, Working Capital Requirement, Two-Echelon Supply Chain, Inventory Routing Problem, Product Allocation Problem

1 Introduction

A historical connection existed between the word "logistics" and military operations, with the latter emphasizing the effective transfer of supplies and equipment during conflicts. However, the idea began to find wider application in business by the 1960s, moving beyond the military. [2]

The main goals of logistics management are to efficiently move goods, services, and related data from the point of origin to the point of consumption by planning, carrying out, and controlling the forward and reverse flow and storage of these resources. Logistics is an essential component of Supply Chain Management (SCM). It ensures everything runs smoothly on the operational side by optimizing transportation, warehousing, and inventory management, etc.

SCM is in charge of the overall strategy and integration of the entire supply chain. From this perspective, SCM can be characterized as the process of decision-making that efficiently combines the different elements of the chain to

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ensure that products are produced and delivered in the appropriate amounts, at the appropriate time, and to the appropriate destinations. The goal of this integration is to meet service-level requirements and customer expectations in the most cost-effective and timely manner while optimizing system performance, either by maximizing profits or minimizing costs.

Few studies show a direct correlation between SCM and financial performance; instead, the impact is frequently indirect. To truly understand the impact of SCM on financial performance, a comprehensive approach that takes into account both external market dynamics and operational improvements is necessary. [1]
SCM must be viewed holistically by organizations, taking into account both short-term operational gains and long-term financial implications. Organizations will be in a better position to identify and take advantage of the possible financial gains from optimized supply chain procedures, which will ultimately improve overall performance.

The integration of Working Capital Requirement (WCR) into SCM models is crucial for aligning operational efficiency with financial health. WCR represents the capital needed to fund daily supply chain activities, including inventory, receivables, and payables. Incorporating WCR into SCM ensures that inventory levels, procurement cycles, and cash flows are optimized to minimize costs while maintaining liquidity. Effective WCR management helps companies avoid over-reliance on external financing and enhances overall supply chain performance. As a result, WCR is so important in assessing an organization's liquidity and financial health.

The optimization of Working Capital Requirements in hospital supply chains is an emerging area of interest, with significant implications for financial and operational efficiency. However, critical questions remain unexplored: What are the current findings regarding WCR optimization in hospital supply chains, and what gaps in the literature need further exploration? At which decision-making levels has WCR been integrated, and how effectively has it been utilized in the context of supply chain models? Addressing these research questions is essential to understand the extent of WCR integration across strategic, tactical, and operational levels, as well as to identify opportunities for innovative approaches that align financial considerations with the unique demands of hospital supply chains.

We followed a research methodology using databases such as Google Scholar, DBLP, Springer, ResearchGate, etc, focusing on keywords like "Working Capital Requirement", "Working Capital Management", "Supply Chain Management", "Inventory Routing Problem", "Allocation problem and Working Capital Requirement", and "Inventory Routing Problem and Working Capital Requirement". Given the limited number of studies on WCR in SCM, we decided to include all available research on this topic without any exclusion criteria to provide a comprehensive overview of the existing literature.

The remainder of this paper is structured as follows: A Two-echelon Supply Chain literature review is presented in Section 2. A literature review of the

Inventory Routing Problem and the Product Allocation Problem are presented respectively in Section 3 and Section 4. We outline the studies that evoke the WCR literature review in Section 5 and a discussion is provided in Section 6. Section 7 presents a conclusion and suggestions for future research.

2 Two-echelon Supply Chain literature

Studies addressing different decision-making levels, supply chain features, and methodology may be found in the literature on two-echelon supply networks.

2.1 Decision making levels

Strategic research frequently focuses on long-term decisions like facility location and supplier selection, to design efficient networks that save costs while improving service levels. The study of Mak et al. [20] is positioned within the strategic level, they created a two-echelon spare parts inventory system that balances costs and service levels using a Mixed Integer Non Linear Programming formulation and Lagrangian heuristic. This system showed significant cost savings over a single-echelon system.

On the other hand, tactical choices deal with medium-term issues like product allocation and inventory control. Within the tactical context of SCM, Dorgham et al. [8] placed special emphasis on long-term decisions that optimize hospital structure and collaboration. Their LP method applied a horizontal collaborative logistics strategy to rationalize and pool resources, reducing costs and enhancing service quality. Moreover, short-term activities like order fulfillment and transportation scheduling are handled by operational-level models. Researchers have addressed the Inventory Routing Problem (IRP) in a Two-echelon supply chain by merging the tactical and operational levels. [15, 21, 22] studies investigate integrated techniques to improve supply chain operations' efficiency and responsiveness.

2.2 Environment characteristics

The contexts vary from stochastic settings, where uncertainty in supply, demand, or lead time is taken into account, to deterministic situations, where all parameters are known. There is a notable deficiency in the literature since only a few works like [23] have addressed stochastic environments.

2.3 Supply chain characteristics

The number of suppliers, goods, and warehouses raises the complexity of these systems. Several studies have addressed logistics operations and resource allocation optimization in multi-depot, multi-product, multi-supplier environments, such as [22,23]. By adding realistic aspects like capacity restrictions, transportation expenses, and service level criteria, these studies improve the applicability of models to real-world scenarios.

2.4 resolution methods

Exact methods, such as mixed-integer linear programming (MILP), are commonly employed for small instances. However, as shown in [15, 22], which highlight their efficacy in producing good solutions within reasonable computational times, heuristic and metaheuristic methods—such as genetic algorithms and particle swarm optimization—are preferred for larger, more complex models.

3 Inventory Routing Problem literature

By striking a balance between transportation expenses and supply chain demands, the Inventory Routing Problem literature (IRP) seeks to optimize operations. It aims to reduce total costs while keeping stock availability by fusing inventory control with route planning. Improving service quality and logistical efficiency requires an integrated approach [14].

In [15] a two-level supply chain in which a manufacturer distributes goods via its network of points of sale has been discussed. They formulated it as a MILP problem with multi-product and multi-vehicle. They created a two-phase metaheuristic that combines techniques from Simulated Annealing and Genetic Algorithm to solve this. The optimization function reduced all expenses, including lost sales, transshipment, inventory, and transportation. Computational tests on 660 benchmark instances show the effectiveness of the algorithm and the noteworthy financial advantages of inventory sharing among points of sales.

The integration of SCM into the healthcare sector was examined in [27], which focuses on private hospitals in Bangladesh. SCM, which has historically been used in manufacturing, can improve hospital and other service industry operations. An Integrated Private Hospital Supply Chain Management model was developed by the research after it analyzes the hospital supply chain and identifies important participants and procedures.

[19] investigated an Inventory Routing Problem with Transshipment in a healthcare network that permits transshipment between hospitals to avoid shortages of hazardous and deteriorating pharmaceutical items. A MILP model with two objectives was suggested by them. Ordering, shipping, delivery, pickup, shortage, and inventory holding costs were all included in the first objective's total cost minimization. Reducing the maximum accident loss during distribution was the second goal. The problem was resolved using a Genetic Algorithm (GA).

The complexity of a sustainable healthcare supply chain network was addressed by [18]. In their 2021 study, they presented a novel integrated simulation optimization model. Comparing HFSA-Variable Neighborhood Search (HAFSA-VNS), HFA-VNS, and HACO-VNS, three hybrid meta-heuristic algorithms, the study discovered that HFSA-VNS performed better than the others on several evaluation metrics. The investigation also examined the dynamics of the COVID-19 outbreak. Simulation techniques were used to estimate the amount of medication needed for informed decision-making. The objective functions seek to minimize costs related to setting up distribution centers, inventory management, transportation, production, shortage, and surplus while maximizing social factors.

[17] solved the IRP by minimizing the total cost of inventory and travel as well as the logistic ratio. They suggested metaheuristic algorithms based on Simulated Annealing and Iterated Local Search. Computational tests showed how well both algorithms performed in producing superior outcomes quickly. When it comes to minimizing the logistic ratio, Simulated Annealing significantly outperformed Iterated Local Search.

[26] presented a new MILP model for Blood Supply Chain Networks with the goal of minimizing overall expenses and increasing donor satisfaction through shorter wait times. To improve understanding of blood donor attendance and service efficiency, the model took into account important variables including the location of blood collection centers, donor allocation, inventory control, and queuing systems. A real-world case study was solved with the help of a metaheuristic algorithm.

[16] optimized liquid oxygen transportation by minimizing the logistic ratio, defined as the operating cost divided by the delivered product amount, incorporating driver-related expenses, travel distance, and layover costs. They used a heuristic algorithm tailored for a diverse truck fleet. Their approach considered constraints like time windows, safety thresholds, and maximum driving times. By combining local search methods with the Metropolis criterion, they achieved competitive results compared to previous studies.

A Mixed Integer Non Linear Programming Model was presented in [21] with the goal of minimizing medication deterioration at hospitals and central pharmacies while optimizing inventory management in a two-tier Pharmaceutical Supply Chain . In order to minimize transportation and storage expenses and prevent medication spoilage, the model gave the best times and amounts for shipments, guaranteeing a steady and effective supply.

4 Product allocation literature

The allocation model optimizes operations by balancing product allocation with supply chain demands. Inventory management and distribution planning are integrated to lower overall costs and guarantee product availability. Improving service quality and logistical efficiency requires a comprehensive approach to product allocation across the supply network.

The issue of allocating stock-keeping units (SKUs) to various kinds of distribution centers (DCs) in a retail network was tackled by [4] The strategy optimizes inventory allocation while lowering operational costs associated with picking, in-store logistics, and outbound/incoming transportation by using a Mixed Integer Programming (MIP) model. When the model was used in a real-world European grocery retail scenario, cost savings of 6% were realized. Sensitivity studies demonstrated the solution's resilience. Through the integrated planning tool for

SKU allocation, the research advances the field and improves the effectiveness of retail supply chains.

[12] presented effective algorithms for two delivery patterns by combining the transportation planning and inventory allocation problems into a single model. The first example reduced shortage and out-of-date costs by posing a straightforward convex inventory allocation problem. In the second pattern, a vehicle routing problem (VRP) is integrated with inventory allocation through an integrated approach. Results show that the combined approach slightly reduces overall costs, especially for perishable products, by optimizing both allocation and routing

In their approach to warehouse design, [13] developed a mathematical model and a heuristic algorithm to solve the problems of product allocation and functional area size determination simultaneously. With the use of readily available warehouse data and realistic constraints, they have reduced the yearly costs associated with handling and storage. The model ensured effective use of warehouse space and resources by optimizing the allocation of products to functional areas such as order collation, cross-docking, and storage.

[8] suggested a linear programming model for the optimization of a cooperative hospital supply chain inside a Territory Hospital Group, with an emphasis on multi-product, multi-supplier, and multi-warehouse logistics pooling. The model reduced ordering, transportation, inventory holding, and purchasing costs by organizing product pooling and optimizing storage locations. By examining different supply chain arrangements, [10] sought to maximize healthcare logistics for medication management in the face of financial constraints. To evaluate 24 configurations that incorporate various transshipment policies, reorder strategies, and service levels, their study used a discrete-event simulation model across three echelons: suppliers, central stock, and hospitals. In general, the results offered significant perspectives for enhancing healthcare logistics while preserving acceptable service standards.

A robust mathematical model based on open innovation principles was presented in [25] to optimize profitability in the Medical and Wellness Tourism Supply Chain (MTSC). The model addressed important issues like controlling tourist flow, service levels, and the capacities of medical facilities, hotels, and tourist routes. It drew attention to the necessity of larger medical facilities in order to handle a 30% increase in the number of tourists. A case study illustrating the model's application provided practical suggestions for raising service standards, optimizing profits, and encouraging long-term economic growth in the industry.

5 Supply Chain and Working capital requirement literature

[24] offered a thorough assessment of the literature on supply chain management, or SCM, in the healthcare industry with an emphasis on hospital supplies and pharmaceuticals. They evaluated 43 significant studies to optimize supply

chains for cost-effectiveness and service quality. Merely 15% of papers employed mathematical modeling to optimize inventory and operational costs, indicating a significant gap in the literature.

This oversight emphasizes the necessity of using more analytical techniques to boost productivity and cut expenses in healthcare supply chains.

Nevertheless, neither the integration of financial indicators nor the WCR in the context of supply chain management were covered by any of the reviewed studies.

Through the management of a company's assets and liabilities, such as inventory, accounts receivable, and accounts payable, working capital management (WCM) is crucial to preserving its financial stability.

Many studies have explored various aspects of working capital management such as Senthilnathan's work on WC. The study emphasized the importance of WC. WC serves as a financial safety net for unforeseen expenses and is essential for maintaining seamless daily operations. To balance liquidity and profitability, which are normally inversely correlated—higher liquidity frequently results in lower profitability and vice versa—the study highlighted how important effective WC management is. Extensive information on WC policies, liquidity management techniques, and optimal cash management models is provided by this research, which covers key topics in WC management [3].

The challenges posed by the mismatch between product deliveries and cash collections or disbursements are highlighted by [4] as they examined the intricacies of managing financial flows within the supply chain. This disparity affects working capital and compels businesses to look for increased financial flow visibility, just as they do with physical flow visibility. Days Sales Outstanding (DSO) reduction, Days Payable Outstanding (DPO) extension, and improved inventory management are just a few of the working capital optimization techniques covered in this paper. It explored supply chain finance and collaborative finance as ways to improve financial performance and introduced a payment scheduling model to improve cash flow and cut costs.

The study conducted by [5] on WCM enhanced operational efficiency by optimizing inventory, accounts receivable, and accounts payable. A company's ability to quickly convert investments into cash is measured by its cash conversion cycle (CCC), where a lower CCC indicates lower financial costs. As one company's payable period is another's receivable, minimizing CCC leads to conflicts amongst supply chain participants. This study uses a simulation-based optimization (SBO) model to determine the best inventory and financial parameters to balance CCC, greatly lowering it for upstream entities and raising it for downstream members.

Several studies have specifically addressed the significance of the WCR, a good indicator of a company's financial health, in ensuring operational efficiency. The WCR is a crucial factor in determining out how much capital is needed to fund continuous operations in the supply chain. Effective WCR management guarantees on-time payments and product availability while maximizing cash flows and lowering expenses. In the context of SCM, WCR must be in line with operational demands to keep the supply chain running smoothly while improving overall performance and profitability. Sufficient WCR management promotes operational effectiveness, easy cash flow, and overall business stability.

The WCR financial cost has also been incorporated into supply chain optimization models. When decisions are made about procurement, production, and distribution, the cost of funding inventory, accounts receivable, and payable are taken into account. This methodology makes it possible to assess supply chain performance more thoroughly by considering both operational and financial costs.

In [6] established a novel connection between dynamic lot-sizing issues and WCR, which are critical for businesses in times of crisis. They created two models: a dynamic lot-sizing-based profit maximization model and a generic WCR model that takes the time value of money and financing costs into account. Their WCR model was more significant than classical models because it can maximize profit and evaluate demand profitability. They proved this by using a polynomial algorithm and the zero-inventory ordering property.

The two-level supplier-manufacturer scenario in [7] expands the single-level lot-sizing problem to include WCR considerations. To solve the two-level case and validate the Zero Inventory Ordering (ZIO) property, they suggested sequential and centralized approaches. They also created an algorithm based on dynamic programming that takes level interdependency into account. Their research highlighted the importance of financial considerations in multi-level supply chain planning by revealing variations in the best plans and the effect of payment delays on WCR through numerical testing.

[9] stressed the importance of free cash flow for effective risk management to address the problem of securing bank loans during financial crises. They integrated an operation-related WCR model, taking into account WCR financing costs, to expand the traditional Economic Order Quantity (EOQ) model. Due to additional cost trade-offs, their approach resulted in a new production lot size policy that is smaller than that of the traditional EOQ model. The effectiveness of their model in tactical planning was further confirmed by sensitivity analysis and numerical examples.

Despite the critical necessity of incorporating WCR into IRP, there is a notable absence of research that combines these two areas. An all-encompassing strategy for financial and resource management requires the integration of WCR with IRP. Nevertheless, this intersection has not yet been sufficiently addressed in current studies. This gap points to a crucial area that needs more investigation and advancement. The integration of WCR into the traditional IRP is addressed by [8] who presented the Two-Echelon Inventory Routing Problem under the Working Capital Requirement (2E-IRP-WCR) model. They reduced the overall cost which includes financial costs as well as costs associated with ordering, inventory, and transportation. Numerical experiments on multi-supplier, multi-warehouse, and multi-customer scenarios show how well their method helped to optimize SCM's financial and logistical aspects. The proposed method provided exact solutions. However, this approach reached its limits for large input instances.

6 discussion

Table 1 helps to categorize different works related to SCM and the integration of the WCR.

The integration of finance measures that evaluate organizational health and lower costs is still lacking, despite significant developments in SCM. While some research investigates measures like WCR, few studies fully discuss how these indicators may be used to support supply chain goals like sustainability and improving service levels.

The literature reveals a notable absence of Working Capital Requirement (WCR) optimization in hospital supply chains, particularly at the strategic decision-making level. While WCR has been explored in tactical and operational contexts, such as inventory management and lot-sizing, its integration into broader strategic problems like network design or long-term resource planning is largely overlooked.

Moreover, there is limited research connecting WCR optimization with other financial metrics, such as profit margins, cash flow, or return on investment, which could provide a more comprehensive understanding of financial efficiency. This gap highlights the need for models that incorporate WCR alongside other financial parameters, especially in hospital supply chains where resource constraints and demand variability require robust financial and operational coordination.

Future research on Working Capital Requirement (WCR) optimization presents several key directions. One promising area is integrating WCR with product allocation models to enhance financial and operational decision-making. In multi-echelon supply chains, exploring WCR optimization across multiple levels can address complexities involving suppliers, warehouses, and customers. Another critical focus is assessing the long-term impacts of WCR optimization on supply chain sustainability and resilience. Additionally, developing WCR models that account for demand fluctuations and uncertainty is essential for improving robustness in dynamic environments. Cross-functional impacts of WCR, such as its influence on procurement, production, and distribution, also warrant further study to identify synergies and trade-offs. Finally, sector-specific investigations, particularly in healthcare, can provide tailored strategies to manage the unique challenges of resource constraints and variable demand. These directions underscore the importance of advancing WCR research to align financial and operational efficiency in supply chains.

7 Conclusion

Efficiency and customer satisfaction are two key goals of Supply Chain Management. The limited integration of financial metrics in Supply Chain Optimization

Paper	WCR	Objective	Approach	Application
Fedrgruen et al.1985		Min SC and outdating costs	Heuristic method	Allocation Problem
Heragu et al. 2005		Min HC and handing cost	Heuristic method	Allocation Problem
Mak et al. 2008		Min HC SC LC	Iterated Local Search Approach	IRP
Bian et al. 2016	✓	Max P	Exact method	Lot sizing
Holzapfel et al. 2018		Min picking cost HC, TC	Exact method	Allocation problem
Alvarez et al. 2018		Min HC and travel cost / Min logistic ratio	local search and simulated annealing	IRP
Timajchi et al. 2019		Min OC, TC, DC ,PKC , SC, HC, accidents	matheuristic (GA)	IRP
Bian et al. 2020	✓	Max P	Exact method	Lot sizing
Dorgham et al. 2020		Min PC, HC, TC, FC, OC	Exact method	Allocation problem
Goodarzian et al. 2021		Max social factors, Min EC, HC, TC, PC, PRC, SC, SRC	HACO-VNS, HFSA-VNS, HFA-VNS	IRP
Bian et al. 2021	✓	Min PR, HC, PC, WCRC	Exact method	Lot sizing
Achamraha et al. 2022		Min HC, TSC, RC	CH/two-phase matheuristic (GA + SA)	IRP
Alonso-Pecina et al. 2024		Min Logistic Ratio	Iterated Local Search Approach	IRP
Daldoul et al. 2024	✓	Min TC, HC, PC, WCRC	Exact method	IRP
Romdhani et al. 2022		Min TC, HC, SH	Exact method	Inventory management
Aghsami et al. 2023		Min Total cost	Metaheuristic method	Allocation Problem
Dinkoksung et al. 2023		Max P	Exact method	Allocation Problem

Table 1: Models discussed in literature

Note **P** Profit, **TC** transportation cost, **PC** purchasing cost, **HC** holding cost, **WCRC** WCR Financing cost, **PR** production cost, **FC** Full-time equivalent cost**RC** routing cost, **TSC** transshipment cost, **DC delivery cost**, **OC ordering cost**, **PKC pickup cost**, **SC shortage cost**, **PRC production cost**, **EC** establishment cost, **SRC** surplus cost, **CH** Constructive Heuristic,**SH** Shipment cost,**LH** Location cost.

restricts the ability to enhance resilience, efficiency, and alignment with sustainability goals in supply chains. Potential areas of future study include Working Capital Requirement in the Inventory Routing Problem and Product allocation problem optimization models. The objective of our next study is to create a model that uses a two-echelon Inventory Routing Problem architecture with Working Capital Requirement consideration.

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