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Development of a Schedule for Product Relocation to a New Warehouse Aimed at Minimizing Split Deliveries During the Relocation

Introduction

This master's thesis was conducted at Bausch + Lomb, a global leader in eye health products with a fully integrated supply chain. One of its key logistics hubs, the Amsterdam Logistics Center (ALC1), manages 50,000 unique products across 300,000 storage locations.

Due to sustained business growth, Bausch + Lomb is relocating its operations from ALC1 to a larger facility, ALC2. This multi-month transition must be carefully managed to ensure uninterrupted customer order fulfillment. A key challenge during this process is the occurrence of split deliveries, situations where items from a single customer order are stored in both warehouses and shipped separately. This leads to higher operational costs and reduced customer satisfaction.

The objective of this thesis is to design and validate a decision model that schedules product relocation in a way that minimizes split deliveries throughout the relocation.

Research Design

To address the relocation challenge at Bausch + Lomb, three methods were developed and compared: a three phase method, an iterative three phase method, and a naïve method.

The three phase method consists of:

Group Size: SKUs are grouped per day based on their handling time and the available daily capacity (N_{max}) in ALC1.

Group Allocation: Using historical order data, SKUs are clustered to minimize split deliveries by reducing the number of out-links (frequently co-ordered SKUs placed in different groups). Three approaches were tested: a mathematical model (optimal but slow), a K-Link clustering algorithm, and an improved Exchange Moving Strategy (EMS), which achieved near-optimal results in under a minute and was selected.

Group Order: This phase sequences the relocation groups to minimize split deliveries over time. The problem resembles a history-dependent Traveling Salesman Problem. While a MILP model finds the optimal sequence, a Genetic Algorithm provided nearly identical results (0.18% difference) in just 48 seconds and was chosen for further use.

The iterative three phase method improves upon the standard method by updating handling times weekly, based on more recent data. This dynamic approach allows better alignment between planning and real-time conditions.

Finally, a naïve method was included as a benchmark. It sorts SKUs by handling time and assigns them to days based solely on daily capacity, without considering product relationships.

Results

Effect of Group Capacity

Split delivery percentages were used as the key metric, across different values of daily handling capacity (N_{max}). Higher N_{max} values result in fewer split deliveries, as more SKUs can be grouped per day, reducing the number of relocation days. The naïve method consistently performed worse due to its lack of order-based logic. When relocation fits within a 5-day workweek, both methods perform equally. Beyond that, the iterative three phase method shows slightly more splits, not due to lower performance, but because it accounts for more realistic, updated constraints during the relocation.

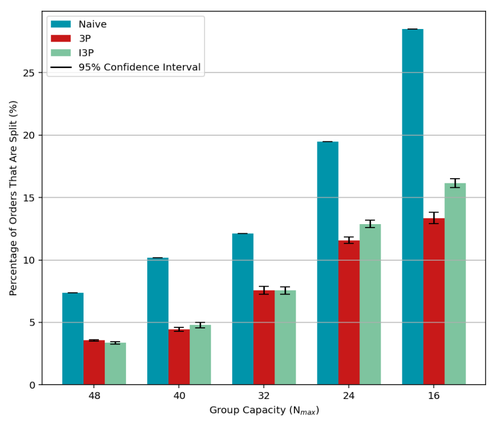


Figure 1: Relationship N_{max} and Percentage of Actually Split Orders

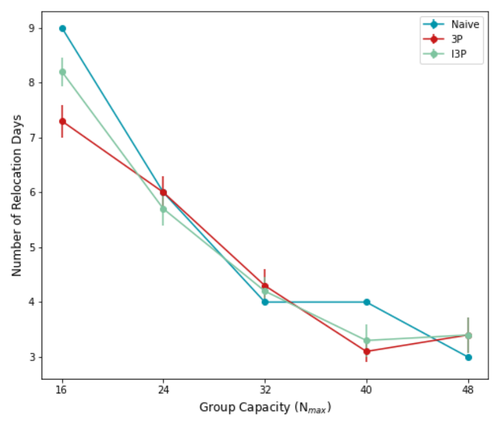
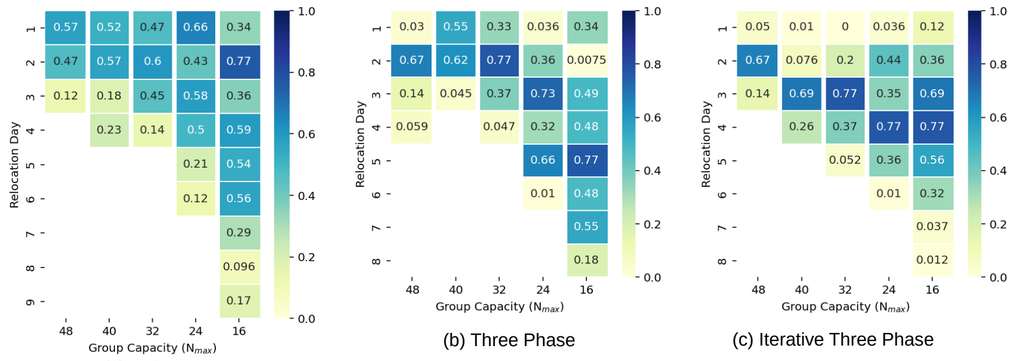


Figure 2: Relationship N_{max} and Number of Relocation Days

Order Frequency vs. Relocation Order

The naïve method places high-frequency SKUs early in the schedule. In contrast, the advanced methods place them mid-schedule. This minimizes splits, as frequently ordered SKUs often co-occur with many others. When scheduled centrally, they are better positioned to overlap with both early and late groups, improving delivery consolidation.



(a) Naive (b) Three Phase (c) Iterative Three Phase

Figure 3: Average Normalized Order Frequency per Relocation Day Across N_{max}

Conclusion

The results lead to three main recommendations. First, maximizing group capacity consistently reduces split deliveries and can be adapted to context-specific constraints. Second, a structured, phased approach, covering group sizing, product allocation, and sequencing, offers a scalable and manageable way to execute complex relocations. Lastly, even without advanced algorithms, a simple rule of scheduling high-demand SKUs in the middle phase can already help reduce split deliveries.

This thesis contributes to the literature by addressing the product relocation problem, which has not yet been addressed in the academic literature. It also introduces a new variant of the Traveling Salesman Problem, where the cost depends on the entire sequence of previously visited nodes, rather than just the most recent one.

Future research could explore combining the three relocation phases into an integrated model, enhancing the algorithm for high-SKU relocations, and incorporating soft capacity constraints to further reduce split deliveries and improve overall flexibility.

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