Integration of the Warehousing and Transportation Functions in the Supply Chain

Xie Zhongqing
School of Transportation, Wuhan University of Technology, Wuhan, P.R.China, 430070
(E-mail: xiezq@whut.edu.cn)

Abstract This paper examines the total cost benefits that can be achieved by suppliers and warehouses through the increased global visibility provided by an integrated system. A discrete event simulation model of a multi-product supply chain was developed to examine the potential benefits to be gained from global inventory visibility and trailer yard dispatching and sequencing techniques. Experimental results demonstrate the potential for this integrated paradigm to improve customer service through improved efficiencies, reduced costs, and reduced lead-time variability.

Key words Warehouse management systems; Transportation; Logistics; Supply chain management

1 Introduction

The Internet has provided a lower cost way of placing an order, and warehouses are experiencing more frequent, smaller quantity orders (Szgenda, 1999). This makes the task of consolidating orders to economic shipment quantities more challenging. It also forces companies to confront the trade-off between quick-response (more frequent shipments) and inventory carrying cost. Real-time information of the product flow becomes the tiebreaker for both sides of the business equation in terms of trading off transportation and inventory costs (Szgenda, 1999).

WMSs often contain information on operational efficiencies and cross-docking requirements, wherein a product is received in a facility, occasionally grouped with other products to the same destination, then shipped at the earliest opportunity without going into long-term storage. Most researchers have approached the management of inventory from an operational perspective. These include deployment strategies (push versus pull), control policies (determining optimal levels of order quantities and reorder points), and safety stock level setting at each stocking location. These safety stock levels are critical, since they are the primary determinants of customer service levels. From the WMS point of view, the only way to handle more shipments is by knowing items' characteristics a priori, such as item dimensions, location, and destination flexibility and visibility.

TMS are typically used as decision support tools in two areas: planning and optimization and transportation execution. In planning and optimization mode, TMSs determine the transportation mode(s), manage freight consolidation operations, and coordinate company shipments, including continuous freight moves (5–8% of the total freight payment). In execution or operations mode, TMSs are either directly or indirectly responsible for carrier load tendering, routing and scheduling, shipment tracking and tracing, and freight payment and auditing (Gilmore and Tompkins, 2000).

Today's supply chain management systems must provide real-time data and integrate data across the supply chain with real-time decision making. As the primary tools in supply chain execution, both WMSs and TMSs are the key factors to integrate the physical flow of goods along the extended supply chain, whose best management is achieved through integration between WMS and TMS (Gilmore and Tompkins, 2000).

Currently, most WMS and TMS systems are not fully integrated; however, the industry as a whole is moving quickly toward process-level synchronization (Gilmore and Tompkins, 2000). Through information exchange, inventory visibility, and intelligent decision support software, shipping firms are trying to reduce their operational costs to maintain current customer satisfaction levels. The integration of WMS and TMS should facilitate the reduction of suppliers' operational costs, thereby resulting in a decreased product cost for the end customer.

2 Integration of WMS and TMS

How WMS and TMS can integrate to reduce the overall costs within a supply chain and reduce lead times (LTs) with increasing reliability is the goal for today's systems to work like one unified and seamless application (Gilmore and Tompkins, 2000). Suppliers, retailers, and carriers need to share inventory levels, production schedules, demand (inbound/outbound orders), product characteristics (dimension, location, destination), available resources (transportation mode characteristics, warehouse capacity), and business rules (delivery-driven shipments).

One integrated TMS and WMS approach is provided by SAP, Inc., an example of the functions of a typical integrated system.

The order fulfillment process begins with a group of orders transferred from the enterprise resource planning system or a Web storefront to the order management system. The orders then pass to the WMS to manage the planning for the packing process, including preparing the boxes and containers to fill the orders in the warehouse. The TMS analyzes the best way to source and ship the orders, thereby saving the time once lost by segregated WMS and TMS operation. The TMS can also examine real-time inventory levels at multiple facilities and, based on optimum transportation costs and customer service, identify which facility should be used to fill the order (Gilmore and Tompkins, 2000). Inventory visibility and real-time order tracking also make it possible to synchronize shipments from multiple facilities in saving inventory and documentation cost.

The planned orders are then passed back to the WMS to initiate the picking process. Meanwhile, the TMS schedules pick-up with the appropriate carriers. The TMS can print shipping labels and documentation as well as verify the load before it leaves the facility. When the order is delivered, the TMS can audit the order, initiating the payment process. Post-shipment information may also be used for analysis of the carrier's reliability when rate negotiations come up again.

To effectively exchange information, transportation providers must become a full part of information collection and distribution. The use of automated data collection (ADC) by transportation providers allows effective implementation of several cost saving and service improvement initiatives, such as Quick Response. One example of these is the advance ship notice (ASN) which notifies customers immediately when goods have been shipped. As incoming goods can be pre-allocated into designated inventory space, they can be rapidly put away or cross-docked, reducing material handling, inventory, and documentation costs. Through barcode scanning at point of shipment and similar technology through the transportation chain, an integrated WMS/TMS can ensure accuracy and electronically report discrepancies.

3 Potential Benefits of the Integration

Potential benefits should arise from the integration of WMSs and TMSs. Lead-time variations for inbound or outbound shipments constitute a significant cost by increasing the amount of safety stock. Companies often hold 15–50% excess inventory or safety stock to compensate for market fluctuations, forecast inaccuracies, and transportation delays (Minahan, 1998). Since inventory holding costs can total between 20% and 40% of inventory value, the need for the efficient management of supply chain inventories is evident.

An integrated WMS/TMS system can help minimize lead-time variations and then large inventory buffers will not be needed. It can generate solutions using real-time product visibility when carriers experience problems on their route or orders are cancelled by rerouting orders to make efficient use of driver time and to satisfy urgent customer needs.

On the supplier side, the increased real-time information from an integrated WMS/TMS can reduce lead-time variability through effective management of incoming orders, cross-docking operations, and changes in product orders during shipment. Since it tracks the extended supply chain, integrated WMS/TMS can generate accurate ASNs, reducing logistics costs by enabling pre-allocation of incoming goods, receipt, put-away or cross-docking. It can also use traditional TMS functions to determine time- and cost-effective transportation mode(s) for a given shipment, such as truck, rail, and/or waterway.

In a multi-facility enterprise, the integrated system can decide where to pick the orders so to optimize transportation costs and maximize customer service (Gilmore and Tompkins, 2000). Since carrier reliability influences lead-time variation for suppliers and customers, it is essential that carriers meet their service guarantees; delivery consistency typically saves more money than simply choosing the lowest cost carrier. The increased supply chain visibility allows shippers and customers to track orders in real-time, crucial to warehousing and manufacturing strategies like just-in-time deliveries, vendor-managed inventory, and cross-docking. Thus, assembly goods from multiple facilities could be synchronized at the same place, reducing inventory and documentation cost.

The VW concepts asserts that demand throughout the supply chain is best managed and satisfied through policies and processes that pull material to its point of use rather than conventional means of simply pushing material downstream through the manufacturing. By pulling material to its point of use, certain advantages associated with just-in-time (JIT) manufacturing, such as reduced inventory levels and improved product quality, can be realized without all of the overhead with a JIT implementation (Hopp and Spearman, 1996). The pull philosophy yields immediate results and lasting value as processes are simplified, and inventory levels drop.

4 A Simulation Analysis

To examine the potential benefits of the global inventory visibility paradigm, a conceptual discrete event simulation model of an auto-parts supplier's (''the company'') multi-product supply chain was developed. To analyze the potential cost advantages, the model calculated the total cost of ordering, holding, and back-ordering inventory in the parts supplier's warehouse. This simulation model was developed in Arena and simulated the flow of goods and information in one of the company's warehouse trailer yards. This yard is responsible for satisfying orders from a total of 250 stores in its region. The yard supply chain includes all the inbound and outbound activities by the distribution, warehousing, and replenishment of goods to satisfy orders from the regional stores. The model further assumed that the company's suppliers exist at different locations and replenish the company's warehouse based on the warehouse's inventory order process.

Automobile engines' order/delivery processes were modeled as slow moving items because of demand and inventory allocation. Generally, automobile engines are not stocked because of slow demand, but they are ordered from warehouses when required. However, automobile tires are classified as regular moving items since quantities on-hand are limited due to their physical dimensions. Finally, motor oil is depicted as a fast moving item since it is available and consumed quite rapidly.

Each item is unique such as daily demand, desired warehouse inventory level, reorder quantity, and customer due date. Regardless of the item, the time it takes from customer (store) orders to the warehouse is assumed to be a mean of one day. These orders are then transmitted to the company's suppliers, who respond to the orders with an assumed distributed lead time of one day. The delivery of items to the company's warehouse was modeled as a Poisson process with a mean inter-arrival time of one day.

Store order sizes were estimated from research on average auto-part store's daily consumption. The average daily consumption was then multiplied by 250 stores—to account for all the stores supplied by the warehouse—and then multiplied by the number of days of inventory for each item to be kept at the warehouse. Order due date distributions was developed by comparing each item type's daily store order versus the desired warehouse inventory level. For instance, the oil due date ranges between one half and one days (720–1440 min) because the warehouse's desired inventory level for oil is three days.

When an outbound truck arrives, the simulation model first checks an outbound dock. If the dock is free, the truck engages it and gets loaded. If all docks are busy, the truck waits in the yard until it gets assigned according to the service rule. When global inventory visibility is off, arriving trucks obey given loading/unloading priorities based on the item type being shipped. For instance, fast moving items have higher priorities than regular and slow moving items, and regular moving items have higher priority than slow moving items. To model the servicing of outbound trucks, the warehouse inventory is decreased by the demand size of each truck's order once the truck is docked.

The simulation model was used to perform a three factor, mixed level experiment. The experiment examined global inventory visibility, yard queue dispatching rules, and product ordering frequency. Each of the three design factors and their associated experimental levels are given as follows:

(1) Global inventory visibility on/off
(2) Yard queue dispatching six queue dispatching approaches
(3) Ordering frequency high/low

Global inventory visibility (on/off) and order frequency (high/low) were each evaluated at two levels. Order frequency was evaluated at both high and low levels to see if the frequency of customer orders significantly affected the performance of the global inventory visibility paradigm. Under high frequency ordering, stores place their orders twice a day (or every 12 h) on average, whereas stores place their orders once per day (every 24 h) on average under the low order frequency case. However, the aggregate demand is equal in both the high and low order frequency models. Therefore, stores order one half the estimated daily demands each order under high order frequency.

For all scenarios, the warehouse and the yard capacities are assumed to remain the same. The experimentation focused on how significantly each of the three design factors affect inventory levels, service levels, dock and worker utilization, total cost, and delivery lead time. The simulation seeks to uncover global inventory visibility's ability to reduce lead time and decrease inventory levels, both saving company money and increasing customer retention throughout the supply chain.

The time required to complete a given task is affected by the existence (or lack) of global inventory visibility. For example, under the global inventory visibility paradigm, it is possible to reduce the amount of time required to prepare an order at the warehouse. Inbound operations were divided into labor allocation time, unloading time, put away time, and item storing time. Under global inventory visibility, the time to allocate labor is assumed to be zero, since, due to the integration of WMSs and TMSs, warehouse operators know exactly when the truck will arrive. Further, the amount of time required to locate a truck, and then dispatch it to pick-up an order at the warehouse for store delivery could also be reduced with global inventory visibility. Finally, the costs associated with preparing and handling orders could also be reduced with global inventory visibility due to a reduction in the number of personnel required to complete the task.

As a base case, the simulation first examines standard FIFO processing of trailers in the yard. Additional methods of dispatching trailers (jobs) in the yard that were investigated are: except for FIFO, yard dispatching rules require decision support systems provided only by the global inventory visibility of an integrated WMS/TMS. To use dispatching rules such as CR and WSPT, the warehouse must know the location of its highest priority inventory at all times. Yard dispatching rules, when combined with global inventory visibility; allow the dynamic review of a dock's queues and the re-assignment of trucks. When the queue dispatching rules are used without global inventory visibility, dock's operators are required to check the truck's content manually before they may they assign them a place in line. It is, therefore, much more difficult to review and update dock queues when higher priority trucks arrive.

The simulation would examine which of the above rules are capable of providing superior performance in terms of inventory levels, customer lead times, lead-time variability, and customer satisfaction. The simulation model was run for a period of one year with a suitable warm-up period, in order for the model to achieve a steady state. Batching the time persistent inventory observations in batches of 10 min and performing a cumulative average plot of these numbers prescribed the warm-up period of just over 83 h. Similarly, the number of model replications required for each case was calculated to be 15.

5 Conclusion

By integrating WMSs and TMSs, a VW can be established with information on the past, present, and projected location of each supply chain asset through time. The VW is supported by a real-time decision support system capable of planning, operating, and adapting to the dynamic nature of the supply chain. Our simulation model, though purely conceptual, demonstrated the potential for the VW paradigm to improve customer service through improved efficiencies, reduced costs, and reduced lead-time variability.

The current research has revealed much potential for improvement resulting from an integrated WMS/TMS. However, future research efforts clearly need to identify and assess the costs of providing such an integrated system, as the benefits must offset the required price of establishing an integrated system. The time frame to cover the costs of the integrated system is also important as high initial costs may be offset through consistent, long-term savings. Some costs to be investigated may be initial acquisition (both hardware and software), installation/implementation and maintenance.

The author is currently working with a real world company to perform similar analysis using actual data. Future research need to address in details the mechanisms for this improvement, including process-level improvements, metrics to measure improvement, and implementation issues. Process improvements in current warehousing and transportation practices are necessary for full realization of the benefits of an integrated system, for example, improving trailer pick-up/drop-off visibility.

The VW relies on intelligent tracking technologies and real-time decision algorithms to provide operating efficiencies and global inventory visibility comparable to that achieved in a single-class warehouse (Stuart et al., 1995). Some questions need to be addressed: When would it be profitable to transfer inventory to prevent a stock out, when to transfer the order and ship, and when to split the order and ship from two locations? Under what circumstances (if any) should inventory in transit be diverted?

To quantify operational improvements of an integrated system, a set of metrics needs to be established to ensure that overall supply chain costs are reduced rather than simply optimizing the different components of the supply chain. Potential issues include the coordination of replenishment when a single vendor supplies multiple SKUs so that full-truckload trucking can be utilized. When a pull system is implemented, initially order quantities are smaller due to existing safety stock—not a full-truckload trucking. However, assuming demand does not decrease, the system should reach equilibrium and revert back to full-truckload trucking as soon as the system exhausts the safety stock.

Finally, all implementation issues of the integrated WMS and TMS need to be addressed. To plan the efficient flow of goods from their origin to their destination (often from production to consumption), supply chain planners typically are concerned with two different planning horizons: strategic (long term) and operational (short term). While strategic planning concentrates on planning the flow of products across the supply chain, execution planning is responsible for making strategic plans into reality.

Companies usually spend millions of dollars on software, hardware, and consultants to prepare and optimize their CEO's strategic plans, often with little consideration of executions. They may consider computational (hardware/software) issues and practical/operational issues—including the length of time a customer may be forced to endure expedited shipments until a pull system reaches balance.

References

[1] D. Gilmore, J. Tompkins. Transport Plays Key Role in Supply Strategy[J]. ID Systems, 2000: 8

[2] W.J. Hopp, M.L. Spearman. Factory Physics: Foundations of Manufacturing Management[M]. Irwin, Chicago, 1996

[3] T.L. Landers, M.H. Cole, B. Walker, R.G. Kirk. The Virtual Warehousing Concept[J]. Transportation Research Part, 2000

[4] T. Minahan. 1998. How the Supply Chain Changes Your Job[J]. Purchasing, 1998

[5] R.M. Monczka, J. Morgan. What will Happen and What should You Know[J]. Purchasing, 1998

[7] D.E. Stuart, J. Owen, T.L. Landers. Establishing the Virtual Warehouse. Manufacturing Science and Engineering—1995 (MED-Vol. 2-2, MH-Vol. 3-2). ASME International Mechanical Engineering Congress and Exposition, San Francisco, 1995

[8] R. Szgenda. Information's Competitive Edge[J]. Information Week, 1999: 720