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A Review of Distribution Related Problems in Logistics and Supply Chain Research

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***Abstract*— A comprehensive review of distribution problems in logistics and supply chain management is presented in this paper. We first review the definitions of distribution, and then define it from a new perspective. We also present and compare different taxonomies of distribution networks. Next, the importance and difficulties of distribution research are discussed. The major contribution of this paper is we point out that there are 12 issues in distribution research that need to be addressed. The major conclusion of the paper is that future research needs to address an integrated approach to distribution design and to consider and incorporate the sustainability development concept.**

***Keywords*—** *Distribution, production, inventory, logistics, supply chain management, sustainability*

1. Introduction

Today's business environment has become increasingly competitive. This causes enormous pressure for many companies in many industries. In such an environment, companies need to continuously search for ways to design and manufacture new products, and distribute these products in an efficient and effective fashion. For many years, companies focused their efforts on reducing costs occurring in the manufacturing processes as well as other operations. There are an increasing number of companies looking at distribution and recognizing it as the last frontier for cost reduction.

In 1991, the Council of Logistics Management, a trade organization based in the United States, defined logistics as the process of planning, implementing, and controlling the efficient, effective flow and storage of goods, services, and related information from point of origin to point of consumption for the purpose of conforming to customer requirements. This is a frequently used definition, which originated in the military. Logistics costs are a large portion of the GDP (gross domestic product) of the United States. Logistics costs constituted about 30% of the cost of the products sold in the United States [1]. In a logistics system, distribution cost is typically the highest single expense, which is usually greater than warehousing cost, inventory cost and order processing cost [2]. Distribution has captured management's attention due to rapid wage and freight rate inflation, critical swing of transportation costs and regulation, the high cost of carrying inventory, and oil market uncertainties [3].

Procurement, manufacturing, distribution, warehousing, inventory and information systems are important logistics functions, among which, distribution is a key function in the entire logistics system and the key link between manufacturers and customers in a supply chain. In addition, distribution is a major driver of profitability in a company, because it has a direct impact on both the logistics cost and the customer experience [4]. Accordingly, companies have been taking a variety of approaches to reduce distribution costs in order to reach the goal of reducing overall logistics and supply chain costs. Although product features, quality and price are important factors for customers, logistics and supply chain performance is key to a company's success [5]. A good design of a distribution network could achieve a number of logistics and supply chain goals, ranging from low operational cost to high customer service level.

In this competitive business world, the dimensions of cost, quality, efficiency and customer service level are not trade-offs for a company anymore. They have to be considered simultaneously. To achieve these objectives, optimally redesigning the entire distribution network is critical, and most of the time, necessary. As [6] mentions, distribution is described as "the Economy's Dark Continent" and it is possibly the

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last frontier for cost reduction in the United States. This is even more appropriate in the current business environment, because it is becoming increasingly difficult to reduce costs of raw material and labor.

The distribution problem is a very active research area and has drawn the attention of many researchers. In this paper, we present a comprehensive literature review on distribution related research. The remainder of this paper is organized as follows. In the next section, we present various definitions of distribution, as well as our own; then we describe some characteristics of distribution networks. In Section 3, we discuss the difficulties when conducting research on distribution. Conclusions and future directions are summarized in Section 4.

2. Literature review

2.1 Definition of distribution

Distribution involves a large number of activities over a complex network. Various definitions of distribution are available in the literature. [7] defines distribution as business activities pertaining to the transportation of finished inventory and/or raw materials in a way that they arrive at the designated place, when needed and in usable condition. [7] does not explicitly consider the location of origin or destination points. [4] defines distribution as the steps taken to store and transport a product from the supplier stage to the customer stage in the supply chain. Only two stages are explicitly considered in this definition: supplier and customer. There could be more than two stages in the distribution network, such as a consolidation, break-bulk, or cross-dock distribution centers (DCs).

In this paper, we define distribution as a sequence of activities involving the transfer of products directly from supply points to demand points or via transshipment points such as DCs and warehouses. The supply points could be manufacturing facilities, DCs or warehouses, while the demand points could be customers or retail stores.

2.2 The characteristics of distribution network

There are six categories of distribution networks [4]: (1) Manufacturer storage with direct shipping; (2) Manufacturer storage with direct shipping and in-transit merge; (3) Distributor storage with package carrier delivery; (4) Distributor storage with last mile delivery; (5) Manufacturer/distributor storage with customer pickup; and (6) Retail storage with customer pickup. In categories (1) and (2), the supply points are manufacturers and the demand points are customers. The only difference between these two categories is whether there is a transshipment point between the manufacturer and the customer. The supply points in categories (3) and (4) are distributors (these could be intermediate warehouses) and there are no transshipment points. The two categories provide different delivery options respectively: carrier delivery or last mile delivery. Categories (5) and (6) are relatively unique compared to other categories, which let customers pick up their order either from a manufacturer/distributor or from a retail store. Another taxonomy is as follows [8]. They categorize the distribution function as one of six types: (1) One-to-many distribution without transshipments; (2) Many-to-one distribution without transshipments; (3) Many-to-many distribution without transshipments; (4) One-to-many distribution with transshipments; (5) Many-to-many distribution with transshipments; and (6) Integrated networks.

We categorize distribution networks by means of their supply, demand and transshipment points:

(1) Supply points. Supply points could be manufacturing facilities, intermediate DCs or warehouses, raw material suppliers, retail stores or pickup sites.
   - Distribution from a manufacturing facility could centralize inventories at the manufacturer, which provides a higher level of product availability and is typically used for high value products, with low and unpredictable demand. Another advantage of this type of distribution network is that handling costs could be reduced significantly since the products could be shipped to customers directly from the production line. However, there are several disadvantages, such as high transportation costs, multiple shipments, long response times, difficulty in handling products return and so on.
   - Distribution from an intermediate DC or warehouse allows inventory to be carried in the intermediate facilities. This type of distribution network is good for relatively high demand products. Transportation costs are typically lower and response times shorter. However, since there are additional intermediate facilities, the total facility costs as well

as processing and handling costs tend to be high.

- Distribution from a raw material supplier usually occurs at an early stage of production, and this process is linked to the procurement process. This type of distribution always has a fixed and stable destination, namely the manufacturing plant.
- Distribution from a retail store could reduce distribution costs significantly since retail stores are usually close to customers. This option also provides fast response and return times. But the cost of opening and operating a retail store could be high especially when many retail stores are needed. Accordingly, inventory carrying costs in retail stores could be high too. It is a better distribution choice when customers value response time more than other factors.
- Distribution from a pickup site provides the largest convenience to customers letting them pick up an order, so the distribution costs could be lower than other distribution options. However, to build such a distribution network could be expensive because customers may need many pickup sites to coordinate their demands; also there is a need for an expansive information infrastructure to coordinate between the storage location and pickup location.

(2) Demand points. Demand points could be end customers, retail stores and pickup locations, or even manufacturers and DCs/warehouses. By choosing different distribution destinations, multiple service levels could be obtained and transportation costs could be reduced. We describe some characteristics of distribution networks with different destinations here.

- Shipping directly to end customers could have different distribution costs depending upon the origin and destination points. An advantage here is that after an easy and fast order placement, orders will be delivered directly to end customers.
- Distribution to retail stores could lower transportation costs because the online or telephone orders can be delivered to the stores, from where customers can pick up.
- Distribution to pickup locations could reduce transportation costs significantly. This distribution option allows customers to pick up their orders at their desired time and location.
- Distribution to supply points, e.g., manufacturers.
- Distribution to intermediate transshipment points and warehouses.

(3) Transshipment points. We classify a distribution network based on the existence of a transshipment point. We refer to a distribution network without transshipment points as a two-stage distribution network, and refer to a distribution network with one or multiple transshipment point(s) as a three-stage distribution network or a multi-stage distribution network.

- Two-stage distribution network: There are only origin (supply points) and destination (demand points) in this type of distribution network.
- Three-stage distribution network: Other than supply and demand points, there is also a transshipment point in the distribution network, which is referred to as intermediate facilities. Typically, there are three types of intermediate facilities: consolidation, break-bulk and crossing docking facility.
- Multi-stage distribution network: There may be more than one transshipment facility along the entire distribution network.

3. Issues and difficulties in distribution related research

Accurate and efficient approaches and tools are required to support and enhance the distribution planning process. There are several important factors to consider when designing a distribution network: cost, quality, delivery reliability, service level, lead time, product availability, technical ability, warranties and so on [9]. There are also several issues and difficulties associated with research in the area of distribution (Figure 1).

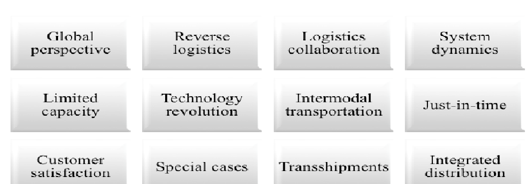

Figure 1. Issues and difficulties in distribution related research

3.1 Global perspective

Global logistics management has become a new discipline attracting the attention of many researchers. Some manufacturers in Asia offer highly efficient and less expensive production. Companies in the United States are under enormous pressure to make their operations more efficient and effective while reducing costs dramatically. Many researchers highlight the importance of coordination and cooperation among all international entities in the entire logistics system in order to improve competitiveness; otherwise, it is impossible for a single entity to achieve its overall goals.

[10] present a comprehensive review of logistics models with a global perspective. These models can choose suppliers and locate plants and warehouses throughout the world. Cash and information flow are important to manage in global operations. Although difficult to model, global distribution must take into consideration taxes and duties, exchange rates, trade barriers, transfer prices and so forth.

3.2 Reverse logistics

[11] published one of the first papers in the reverse logistics area. Reverse logistics represents a way to deal with used products no longer usable or required by the users. There are four important components of reverse logistics: reduction, substitution, reuse and recycle [12].

[13] present an extensive review on quantitative models in reverse logistics. They divide this field into three main areas: distribution planning, inventory control and production planning. In each area, they review the mathematical models and point out directions for future research.

[12] propose a model framework on reverse distribution problems in order to minimize costs to transfer products from origins through collection sites to their destinations and fixed costs of opening the collection and destination sites. They develop a strong formulation and a weak formulation for reverse distribution problems that include product recall, product recycling and reuse, product disposal and hazardous products return.

[14] develop a mixed-integer, nonlinear model for an integrated distribution problem which simultaneously considers forward and return networks. They apply a genetic algorithm-based heuristic and compare it with an exact algorithm on a set of problems.

[15] present a bi-objective optimization model which minimizes the total costs as well as the total tardiness. They develop a solution approach that consists of a combination of three algorithms: scatter search, dual simplex and a constraint method.

3.3 Logistics collaboration

Many companies prefer cooperative decision making to other operation modes. A single dominant company typically optimizes its own logistics decisions regardless of their impact on other companies in this logistics system. Often such an approach is only good for the short run; but in the long run, this approach should build strategic relationships with other companies to form a logistics alliance. To achieve this long-term, win-win relationship, the dominant company plays an important role in fostering cooperative agreements to jointly optimize the entire supply chain [16]. As [16] indicate developing a cooperative relationship with other entities (such as suppliers, carriers) in the entire logistical system is critical to achieving system-wide objectives. However, there are no approaches or tools to analyze the integrated system in this emerging collaborative environment in spite of the awareness and understanding of its necessity [17].

3.4 System dynamics

Dynamics within a logistics system could necessitate a change in the entire distribution network, which in turn could result in an increase in logistics costs including inventory, transportation, facilities and handling, and information changing [4]. At the operational level of distribution planning, variability is observed in scheduling services, empty vehicle distribution or reposition, crew scheduling, allocation of resources and so on [18]. Many uncertainties and qualitative factors can be analyzed via a specification of different scenarios and the performance of sensitivity analysis.

3.5 Limited capacity

Limited capacity is a common phenomenon for many companies. Lack of sufficient production machines, warehouse space, trucks, or even drivers could have a significant effect on overall logistics performance.

[8] point out that backhauls could allow vehicles to make productive use of return trips when finishing line haul distribution, thus avoiding returning empty to their origins. Such an approach would lead to better utilization of truckload capacity. However, for other limited capacity resources, this still remains an open field which requires more research.

3.6 Technology revolution

As the supply chain gets longer and extends beyond national boundaries, effective communication and information infrastructures to support such complex processes and systems become essential [16]. Information technology and telematics allow mathematical models to be applied within real-time systems and process controller. The development of telecommunications and information technology has created many opportunities to increase the integration of logistics functions such as raw material purchasing and the distribution of products to customers. This increases the performance in the entire logistics system and helps achieve a win-win solution for all the participants: suppliers, customers and intermediaries [19].

3.7 Intermodal transportation

Distribution over multiple transportation modes is an important component of transportation science and has attracted many researchers in recent years. However, due to the inherent difficulties and complexities of such problems, the study of intermodal transportation at either the regional or national level has not yet fully matured [18].

3.8 Just-in-time (JIT)

Since the just-in-time concept was first introduced, there have been a wide variety of studies in this area. Small and frequent shipments are required between suppliers and manufacturers in a just-in-time environment, emergency shipments may be necessary for supplying the right volume at the right time in the right place. Emergency shipments are contracted by suppliers whenever there is a sudden increase in customer demand [17]. How to balance regular shipments and emergency shipments to reach the just in time goal is a fertile research topic.

Supplier performance and relationships with suppliers are two important components of a JIT environment. Quality, cost and on-time delivery are the three most important criteria when evaluating supplier performance. Buyers and suppliers have a win-win relationship in a successful JIT implementation [16].

3.9 Customer satisfaction

Satisfying customers' needs is becoming increasingly important because only when customers' needs are met, can the company's revenues be maximized [4]. Managers in a company must not only consider trade-offs among facility cost, inventory cost and transportation cost, but must also focus on customer service issues [5]. [4] also points out that there are many factors influencing customer satisfaction, e.g., response time, product variety, product availability, customer experience, order visibility and returnability. Increasingly, customers not only expect low price, but also demand a high quality service, which is generally measured in terms of speed, flexibility and reliability. Consequently, how to balance operating costs with service performance issues is one of the major concerns for companies. An active research area for academicians is to include these factors into the objective function of the associated models [20].

3.10 Special cases

Distributing special products introduces increased complexity. [21] apply an optimization model to determine daily production, delivery scheduling, and dispatching of natural gas. The joint determination achieves cost savings of between 6 and 10%. [22] develop a model to distribute perishable products (e.g. blood, food, medical drugs) from a regional center to many customer locations and allocate available inventory in a regional center.

3.11 Transshipments

There are two major functions of transshipment facilities: consolidation and break-bulk. Consolidate shipments are used to combine shipments from many scattered origins into larger loads. Break-bulk shipments provide an opposite function to split a large load into smaller shipments.

[23] uses an analytic model to study a one-to-many distribution problem with transshipments.

Transshipments take place in a one-to-many distribution system when vehicles at the origins cannot serve their destinations directly. In other words, the vehicle capacity is limited and the serving area is large. Transshipment facilities are used to transfer loads from line haul vehicles (which travel between origins and transshipment facilities) to local vehicles (which travel between transshipment facilities and destinations). Research shows that optimal decisions on a distribution system are decided by a ratio of load size of line haul vehicles to load size of local vehicles; moreover, distribution with transshipments could increase inventory and terminal costs but reduce transportation costs because of economies of scale. [23] also points out that the transshipments are important in many-to-many distribution systems due to efficient loads through consolidation and break-bulk terminals; sometimes it is necessary to have more than one level of transshipment facilities to further reduce costs.

Distribution systems with transshipment points are often organized hierarchically into separate levels of transshipment facilities [8]. In such a distribution network, economies of scale could be achieved by using different sizes of vehicles at different levels.

3.12 Integrated distribution

Current industry trends show that distribution networks are selected by adopting an integrated perspective [16]. Synchronizing the logistics processes from raw materials supply and production activities to marketing and final distribution choices is another area of research [24]. However, most previous studies treat each component (such as purchasing, production and scheduling, inventory, warehousing, and transportation) separately, thereby ignoring many complex supply chain interactions ([25], [10]).

But there are a wide variety of recent works that have integrated the multiple logistics functions. On the basis of applications and case studies, many researchers have proposed potential economic benefits deriving from an integration of the logistics decision process. For example, [26] present an integrated production-inventory-distribution approach to determine optimal levels of stocks and quantities of production and transportation in order to minimize total costs. [27] incorporates distribution decisions into production decisions (and vice versa). He shows that substantially different solutions result when these two types of decisions are considered independently than when they are considered jointly. Research results show that: (1) considering inventory at both origin and destination could result in a significant difference of batch quantities and cost estimates, but relatively small regret; (2) failure to include consolidation considerations of products that are sent to a common destination could lead to large errors and large regret.

Another review paper on integrated production and distribution systems by Erenguc et al. identifies several future research directions: (1) considering all three stages (supplier, plant and distribution) in the entire supply chain; (2) integrated approaches to managing inventory at different stages; (3) utilization of information sharing in a multi-partner supply chain; and (4) analytical and simulation models that integrate the entire logistics system [16].

Since 1987 when the expression "Sustainable Development" was first used in the World Commission on Environment and Development (WCED) report, many companies have recognized sustainable development/sustainability as their ultimate goal. It is notable that in recent years companies not only search for ways to reduce their costs but also explore opportunities to reduce their environmental impacts and fulfill their social responsibilities. Often, reducing travelling miles (as a result of distribution network improvement) can also reduce corporate carbon footprint. It brings challenges and opportunities for researchers to examine distribution related research as well as sustainability related research.

4. Conclusions

Today's competitive business environment has resulted in increasing pressure for many companies in almost every industry. In such an environment, companies must fill customer orders, accurately, quickly and efficiently. At the same time, they must reduce inventory, implement reverse logistics and consider other important logistical factors. A company's supply chain constitutes several interactive processes, which are important to the integrated logistics system. In order to reduce costs for every single component of a supply chain, companies may have to redesign their supply chain network and consider every operation as part of a whole. After years of focusing on reduction in production and operation costs, companies are beginning to look into distribution activities as the last frontier for cost reduction.

In this paper, we first review the definitions of distribution in the literature and then define distribution from a new perspective. We also compare various taxonomies of distribution networks. The importance of distribution and difficulties associated with the study of distribution are also discussed. We point out that there are 12 issues which should be studied in greater detail: (1) global perspective; (2) reverse logistics; (3) logistics collaboration; (4) system dynamics; (5) limited capacity; (6) technology revolution; (7) intermodal transportation; (8) JIT; (9) customer satisfaction; (10) special cases; (11) transshipments; and (12) integrated distribution. It is notable that distribution research has close relationship with sustainability related research.

In conclusion, all of the entities and activities in the supply chain are highly interrelated to each other by means of material and information flow; as a result, synchronized consideration of production, inventory and distribution is necessary and critical in the study of a distribution problem. An integrated view of the logistics and supply chain design may lead to an improvement in service level as well as substantial savings in total costs. We believe that by focusing the study on the relationship between distribution and other functions in a logistics system, new opportunities can be identified and new results can be proposed.

References

[1] Eskigun, E., Uzsoy, R., Preckel, P.V., Beaujon, G., Krishnan, S., & Tew, J.D., "*Outbound supply chain network design with mode selection, lead times and capacitated vehicle distribution centers*", European Journal of Operational Research, 165(1), 182-206, 2005.

[2] Parthanadee, P. & Logendran, R., "*Periodic product distribution from multi-depots under limited supplies*", IIE Transactions, 38(11), 1009-1026, 2006.

[3] Geoffrion, A.M., Graves, G.W., & Lee, S.J., "*A management support system for distribution planning*", INFOR, 20(4), 287-314, 1982.

[4] Chopra, S., "*Designing the distribution network in a supply chain*", Transportation Research Part E, 39(2), 123-140, 2003.

[5] Robinson, E.P., Gao, L., & Muggenborg, S.D., "*Designing an integrated distribution system at DowBrands, Inc*". Interfaces, 23(3), 107-117, 1993.

[6] Stewart, W.M., "*Physical distribution: key to improved volume and profits*", Journal of Marketing, 29(1), 65-70, 1965.

[7] Bowersox, D.J., "*Physical distribution development, current status, and potential*", Journal of Marketing, 33(1), 63-70, 1969.

[8] Langevin, A., Mbaraga, P., & Campbell, J.F., "*Continuous approximation models in freight distribution: an overview*", Transportation Research Part B, 30(3), 163-188, 1996.

[9] Mentzer, J.T., Gomes, R., & Krapfel, R.E., "*Physical distribution service: a fundamental marketing concept?*", Journal of the Academy of Marketing Science, 17(1), 53-62, 1989.

[10] Vidal, C.J. & Goetschalckx, M., "*Strategic production-distribution models: a critical review with emphasis on global supply chain models*", European Journal of Operational Research, 98(1), 1-18, 1997.

[11] Guiltinan, J.P. & Nwokoye, N.G., "*Developing Distribution Channels and Systems in the Emerging Recycling Industries*", International Journal of Physical Distribution & Logistics, 6(1), 28-38, 1975.

[12] Jayaraman, V., Patterson, R.A., Rolland, E., "*The design of reverse distribution network: models and solution procedures*", European Journal of Operational Research, 150(1), 128-149, 2003.

[13] Fleischmann, M., Bloemhof-Ruwaard, J.M., Dekker, R., Laan, E., Nunen, J.A., & Wassenhove, L.N., "*Quantitative models for reverse logistics: a review*", European Journal of Operational Research, 103(1), 1-17, 1997.

[14] Ko, H.J. & Evans, G.W., "*A genetic algorithm-based heuristic for the dynamic integrated forward/reverse logistics network for 3PLs*", Computers & Operations Research, 34(2), 346-366, 2007.

[15] Du, F. & Evans, G.W., "*A bi-objective reverse logistics network analysis for post-sale service*", Computers & Operations Research, 35(8), 2617-2634, 2008.

[16] Erenguc, S.S., Simpson, N.C., & Vakharia, A.J., "*Integrated production/distribution planning in supply chains: an invited review*", European Journal of Operational Research, 115(2), 219-236, 1999.

[17] Sarmiento, A.M. & Nagi, R., "*A review of integrated analysis of production distribution systems*", IIE Transactions, 31(11), 1061-1074, 1999.

[18] Crainic, T.G. & Laporte, G., "*Planning models for freight transportation*", European Journal of Operational Research, 97(3), 409-438, 1997.

[19] Slats, P.A., Bhola, B., Evers, J.M., & Dijkhuizen, G., "*Logistic chain modelling*",

European Journal of Operational Research, 87(1), 1-20, 1995.
[20] Crainic, T.G., "*Service network design in freight transportation*", European Journal of Operational Research, 122(2), 272-288, 2000.
[21] Bell, W.J., Dalberto, L.M., Fisher, M.L., Greenfield, A.J., Jaikumar, R., Kedia, P., Mack, R.G., & Prutzman, P.J., "*Improving the distribution of industrial gases with an on-line computerized routing and scheduling optimizer*", Interfaces, 13(6), 4-23, 1983.
[22] Federgruen, A., Prastacos, G., & Zipkin, P.H., "*An allocation and distribution model for perishable products*", Operations research, 34(1), 75-82, 1986.
[23] Campbell, J.F., "*One-to-many distribution with transshipments: an analytic model*", Transportation Science, 27(4), 330-340, 1993.
[24] Fumero, F. & Vercellis, C., "*Synchronized development of production, inventory, and distribution schedules*", Transportation Science, 33(3), 330-340, 1999.
[25] Cohen, M.A. & Lee, H.L., "*Strategic analysis of integrated production-distribution systems: models and methods*", Operations Research, 36(2), 216-228, 1988.
[26] Mak, K.L. & Wong, Y.S., "*Design of integrated production-inventory-distribution systems using genetic algorithm*", First International Conference on Genetic Algorithms in Engineering Systems: Innovations and Applications (Conf. Publ. No. 414), 1995.
[27] Hall, R.W., "*On the integration of production and distribution: economic order and production quantity implications*", Transportation Research Part B, 30(5), 387-403, 1996.