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SCHEDULING AND DELIVERY LOGISTICS OF BIO-PERISHABLE GOODS: A REVIEW OF LITERATURE AND RESEARCH OPTIONS

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ABSTRACT

Logistics scheduling, specifically that of order and delivery schedules, is an essential part of a firm and the supply chain. The objective of this paper was to identify any gaps in academic and professional literature regarding the logistics scheduling of perishable biopharmaceuticals. A literature review of the logistics scheduling of general products, perishable medical supplies, and flu vaccines was conducted in order to verify any potential gaps in the literature. The approach used to study this issue was based on the grounded theory concept of qualitative research, and by then focusing on an extensive review of scheduling, ordering, and delivery in these industries. A gap in the literature was identified. The identification of this gap in academic and professional literature regarding logistics of perishable biopharmaceuticals provides a contribution to the body of knowledge. Suggested future research is identified. Finally, research propositions are included to begin to address the research gaps.

INTRODUCTION

Logistics scheduling is an essential part of a firm and the supply chain. How and when a product is ordered and the delivery schedule involved is a determining factor in a company's success and in obtaining a competitive advantage. Learning about logistics scheduling and the importance it has on a company and supply chain is critical in attaining that competitive advantage in an industry. Logistics scheduling of material is constantly reviewed and evaluated and is increasing at a high rate as supply chains expand. Supply chain managers are faced with the issue of how and when to schedule the delivery of products, especially those that are perishable.

Currently, there is a problem in logistics scheduling as it relates to perishable biopharmaceuticals. The objective of this paper is to demonstrate the gap in academic literature regarding logistics scheduling of perishable medical supplies based upon issues with order and delivery schedules in medical and administering facilities. While the assumptions are valid for a wide range of perishable pharmaceuticals, the paper will concentrate on flu

vaccinations. The logistics scheduling of flu vaccinations is used as an example to emphasize the disconnect presented in supply chains and the effect it has on facilities and the customer population. As seen in the literature review, multiple mathematical models have been created to simulate and address scheduling challenges with transportation, personnel, and machinery in general. However, there is little research that has been conducted concerning the logistics scheduling of orders and delivery of perishable materials in the medical field.

Little is known about logistics scheduling of flu vaccinations as it pertains to ordering and delivery of perishable biopharmaceuticals to the medical or administering facilities of pharmacies regardless of whether they are stand alone or located within other retail locations such as big box retailers. Other fields of logistics scheduling have been well researched with multiple theoretical frameworks and mathematical models being developed to help analyze information to promote a firm, industry, or supply chain. However, there appears to be a gap in the information regarding the logistics scheduling of perishable medical supply order and delivery process. The lack of medical industry specific

models and approaches affects medical and administering firms and supply chains across industries all over the world, as well as the populations exposed to various viruses like influenza (i.e., the flu). Clearly, the time sensitive nature of these types of products validates the need to do further examination beyond the generic logistics scheduling and delivery models.

As background, the Centers for Disease Control and Prevention (CDC) lists influenza as a contagious respiratory virus that affects the nose, throat, and chest. The flu can cause mild illness or even lead to death, and this unpredictable virus can range in severity each season. Greater risk groups for contracting the flu are children, elderly people, women who are pregnant, individuals with chronic health conditions, and those living in enclosed facilities, such as nursing homes with 5-20% of the U.S. population getting the flu each year (Flu.gov, 2013). Flu season generally lasts from December to March but can start as early as October and last till May. Between 1976 and 2006, flu-related deaths in the United States ranged from 3,000 to 49,000 each year (CDC, 2013). Because there is little time between the identification of the proper vaccine strain mix and the production of the vaccine, and the beginning of the flu season, it is critical that the logistics system be able to deliver vaccine to many vaccination points in a timely and reliable fashion.

Following this introduction, the article is slightly different than a traditional research paper. The next section of this article is a brief methodology used to identify, examine, and analyze academic articles regarding logistics scheduling using a grounded theory concept of qualitative research. The results of the search are then provided as the basis of the literature review, which is further broken down into sub-categories including logistics, logistics scheduling, and logistics modeling for an overall view of logistic scheduling concepts. Each of those sections are immediately followed by the problems faced in each category. The article then focuses on healthcare logistics scheduling of perishable medical supplies and more specifically the logistics scheduling of the flu vaccination. Afterwards, this

article presents the results from the research and describes the relationships found through the literature review and emphasizes the gap in academic literature regarding healthcare logistics scheduling, with an example of flu vaccinations. Next, the article provides a summary of the literature review along with limitations that were found. Finally, the article addresses future research topics and approaches, and then provides conclusions.

METHODOLOGY

The purpose of this article is to identify issues with logistics scheduling of perishable medical supplies, with an example of flu vaccinations as it pertains to product ordering and delivery. The approach is based on the grounded theory concept of qualitative research presented by Glaser and Strauss (1967). By focusing on an extensive literature review of scheduling, ordering, and delivery, research gaps in the literature were found. For the first half of this literature review, top business journals were the primary focus for this study with the mathematical models for logistics scheduling being mainly from the operations management field. Keywords and phrases of logistics, logistics management, supply chain management, ordering schedule, delivery, logistics ordering, logistics scheduling, and logistics delivery were the main concentration for the search of academic articles to collect an extensive body of knowledge for the topic of logistics scheduling. For the latter half of this literature review, the terms healthcare, medical supply, perishable products, biohazard, vaccination, and influenza were added to the key phrases. Top business journals were once again targeted, followed by an overall sweeping search of all journals, resulting in an emphasis in medical journals. Table 1 shows a summary of the relevant articles reviewed.

LITERATURE REVIEW

Part I: Logistics Scheduling Overview

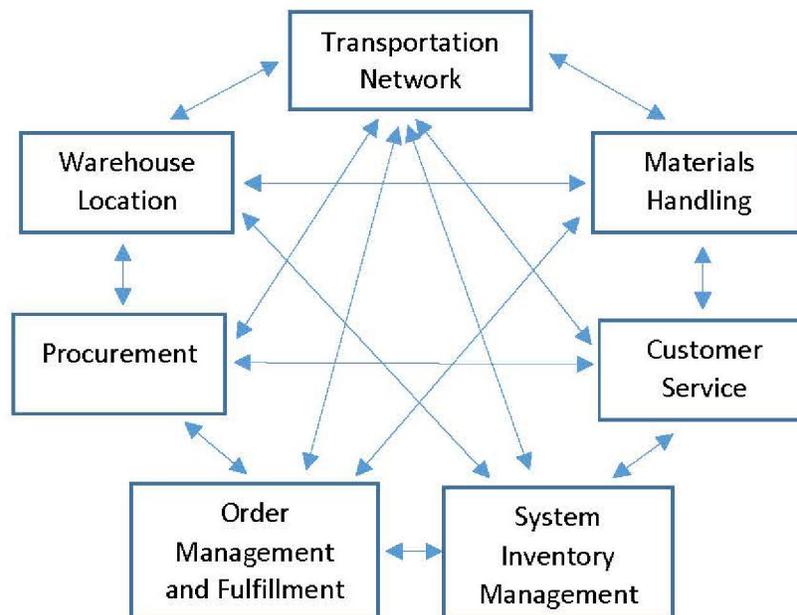
Logistics Opportunities and Issues to gain Competitive Advantage

According to the Council of Supply Chain Management Professionals (2010), "Logistics

TABLE 1
LITERATURE REVIEW SUMMARY OF RELEVANT ARTICLES

	Number of Articles
Logistics Opportunities and Issues	26
Current Logistics Scheduling	18
Perishable Logistics	13
Perishable Healthcare Logistics	3
Scheduling of Perishable Medical Supplies Logistics	18
Flu Vaccination Scheduling	7

FIGURE 1
LOGISTIC DISCIPLINES



management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements." Logistics goals and objectives differ among various strategies and business orientations within the supply chain (Stank, Davis, and Fugate,

2005; Richey, Genchev, and Daughtery, 2005). Logistics is a key factor in developing competitive advantages for businesses and supply chains. (Bowersox, Mentzer, and Speh, 1995; Mentzer, and Kahn, 1995; Novack, Rinehart, and Langley, 1994). Logistics has been defined as including transportation network design, warehouse location and design, materials handling, system inventory management, order management and fulfillment,

procurement, and customer service and spans the entire supply chain (Mentzer, Stank, and Esper, 2008; Kent and Flint, 1997; Lynch, Keller, and Ozment, 2000; Langley, 1986; Langley and Holcomb, 1992; Mentzer et al., 2001). These disciplines are integrated and depicted in Figure 1.

Various methodologies and concepts of logistics have been designed to improve customer service and increase profit while decreasing total costs (Leuthesser and Kohli, 1995; Wolfe, 1990). Logistics capabilities are not only linked to strategy but are also affected by market conditions and competition (Lynch et al., 2000; Van Damme and Ploos Van Amstel, 1996), and the strategic use of these capabilities and competencies can lead to competitive advantage (Esper, Fugate, and Davis-Sramek, 2007; Morash, Droge, and Vickery, 1996; Zhao, Droge, and Stank, 2001). In logistics, multiple components are considered in the decision process to increase conceptual integration (Novack, Rinehart, and Wells, 1992). Supply chain management is becoming more strategic and through the implementation of visibility and aligning the processes and products within the supply chain, is improving its competitive advantage (Bartlett, Julien, and Baines, 2007; Stavroulaki and Davis, 2010).

However, logistics is not a perfect science and has endured a lot of scrutiny and difficulties in being properly designed within a supply chain. Through the faces of innovation in technology, changes faced with deregulation, and even the concept of supply chain itself, logistics has encountered multiple challenges throughout time (Rutner, Aviles, and Cox, 2012). Firms constantly face obstacles to move a product with reliability and predictability to maintain plant operation and supply to its retailers. Innovations in logistics have impacted the business practices for moving products around the world (Grawe, 2009; Grawe, Chen, and Daugherty, 2009).

As can be seen in Figure 1, there is a significant amount of interaction that occurs within logistics to perform even the most basic tasks. Multiple disciplines are constantly interacting with each other across businesses and supply chains. As supply

chains expand, whether with additional players within an existing supply chain or across the globe with new partners, the challenges faced by logistics professionals continue to increase. Perceived expectations and performance evaluations are constantly monitored by customers as a measure of satisfaction (Churchill and Surprenant, 1982). Any changes or challenges across the area of logistics identified in Figure 1 can disrupt the entire flow of the logistics platform. This in turn can affect the firm and supply chain from the single delivery to the strategic level.

The concept of sustained competitive advantage is a factor that is analyzed across firms and supply chains. The factors of value, rareness, imitability, and substitutability have been discussed as the potential indicators of competitive advantage (Barney, 1991). Once these factors are analyzed across the multiple disciplines of logistics, the issues faced by the firm or supply chain are constantly reviewed for the best strategy that can be placed into practice to minimize costs and increase customer satisfaction across the board. Many companies choose to outsource in order to tackle logistical obstacles in hopes of reducing costs but face additional challenges of perceptions, timeliness, strategic orientation, and the release of power and control to another entity (Bolumole, 2001). Given the challenges of a dynamic business environment described in the literature, firms' logistics operations and processes are constantly evolving and expanding as firms and supply chains continue to grow.

Current Logistics Scheduling Literature

Qi (2005) refers to logistics scheduling as providing a single framework to job scheduling and transportation. The relevant literature review shows that a large portion of academic articles are based on either transportation scheduling or the scheduling of people or machines. Transportation scheduling has been examined through the use of structural equation modeling to improve delivery schedules in order to provide a source of competitive advantage to the supply chain (Tracey, 2004). A case study completed at Scottish & Newcastle PLC, a UK brewing company, implemented scheduling software

to apply to vehicle routing scenarios (Eibl, Mackenzie, and Kidner, 1994). Labor scheduling in supermarkets has been analyzed to determine the number of front-end cashiers required as customer volume fluctuates (Melachrinoudis and Olafsson, 1995). Convergent logistics carriers who receive a premium are more inclined to satisfy supply chain participants to reach mutually beneficial goals; in other words, the premium allowed carriers to be more flexible in scheduling options (Wagner and Frankel, 2000). Value-ordering strategies have been developed to address the discrepancies in the generative schedule and current status of a factory by analyzing the reactive scheduling process, such as machine breakdowns, delayed deliveries of materials, and not meeting expectations of quality control and/or customer satisfaction within the factory (Suh et al., 1998). These representative articles highlight the cross section of research that focus upon the scheduling aspect of logistics. By broadening the search to include supply chain articles, similar results of scheduling research were identified. First, Morash and Clinton (1997) conducted a comparison of supply chain structures and global integrative practices as firms and supply chains continue to expand around the world. Scheduling of product order and delivery is constantly under review as supply chains coordinate cross-functional activities across the practices of other firms, suppliers, customers, and entire supply chains. The research highlighted that both internal and external factors must be reviewed and highly involved to allow logistics scheduling to work properly with the right strategy to take place and be successful.

Logistics management is often used to describe the scheduling of the logistics processes. Balancing customer service, inventory, variance, total costs, and quality control by involving scheduled distribution has been analyzed using the computer-based system Materials Logistics Management Program to obtain a competitive advantage throughout the supply network (Bowersox, Carter, and Monczka, 1993). Holweg (2005) describes the problems that occur through logistics scheduling and the constraints felt by suppliers between the raw material supply base and automotive manufacturers.

However, scheduling involves various factors and changes frequently based on the company, product, and supply chain. How scheduling is designed is based on the type of supply chain that is implemented and the product or service provided (Esper et al., 2007; Grawe et al., 2009; Lynch et al., 2000; Mentzer et al., 2008).

The scheduling challenges have been reviewed across a spectrum from simple check methods to integrated mathematical models. On the low complexity end, the balanced scorecard provides a more simplified method in measuring performance across the supply chain and can be funneled to specific areas of the supply chain or within the firm (Barber, 2008). More complex solutions include logistics scheduling analysis to minimize job delivery time and total transportation cost to guarantee performance through algorithm modeling (Chen and Lee, 2008). A heuristic using logistic growth and substitution finds minimal cost of delivery schedules for short life cycle products by modeling growth, saturation, and decline (Chou, Chang, and Yang, 2001). Finally, physical distribution quality, with scheduling as a key component, plays a pivotal role in customer perceptions of service, and valid and reliable models have been developed to measure this perception of service (Biestock, Mentzer, and Bird, 1997; Mentzer, Gomes, and Krapfel, 1989).

However, the models that have been developed do not analyze the actual scheduling problem focusing on the product's order and delivery process. Most focus on the scheduling of transportation, people, and/or machines. While these topics are incredibly important to firms and supply chains, there is a large disconnect in the actual logistics order and delivery process in relation to schedule. When this concept is applied to time-sensitive or perishable products, the need for evaluating ordering and delivery schedule as a significant portion of the logistics process comes into effect.

Part II: Perishable Logistics Scheduling Overview

Perishable Logistics

Nahmias (1982) defines perishable goods as those that "Undergo change in storage so that in time they

may become partially or entirely unfit for consumption.” Perishable products are abundant in the grocery industry and create a unique situation for how a supply chain needs to be designed in order to properly schedule and deliver these products in the best form and in a timely manner to improve customer satisfaction. Focusing on the customer or customer service provided when managing emergency supply chains has shown to be a significant indicator for overall satisfaction (Oloruntoba and Gray, 2009). Also, lead times are of high importance when assessing the potential delays in materials when changes in time-distance or temperature is introduced (Bogataj, Bogataj, and Vodopivec, 2005). Advanced inventory dispatch policies and collaborative replenishment have been studied in discrete event simulations to assess the perishable goods environment supply chain. They determined the use of these advanced inventory distribution policies (i.e., models) improved perishable good supply (Thron, Nagy, and Wassan, 2007). In the food industry, the impact of poor scheduling is often offset with a high willingness to substitute when perishable items are out of stock (Van Woensel et al., 2007). Heuristic assessments show that implementing FIFO policies for perishable products minimizes the number of expired items by 40% as compared to random allocation approaches (Huq et al., 2005). Due to high demand uncertainty and an inflexible production environment, such as in the poultry supply chain, implementing a “leagile” (lean and agile) supply chain is not the most feasible (Van Der Vorst, Van Dijk, and Beulens, 2001).

Another related time sensitive area is seasonal items. Seasonal demand products have received a great deal of research attention due to their unique scheduling challenges. Products such as Christmas items, winter clothing, flowers or any perishable item with a shelf life have been addressed with multiple mathematical models to address these seasonal demand inventory management problems (Gupta, Sundararaghavan, and Ahmed, 2003). Multiple studies examined seasonal sales patterns resulting in the “Seasonal Forecast Delta Model” to maximize profit while determining the optimal sales quantities required during seasonal retail times (Gupta et al., 2003; Groebner and Merz, 1990).

Like all products, perishable items face the need for shortened lead times, order quantity, and selling price. Shortening lead times has been shown to reduce work in progress and inventory as well as to improve responsiveness and flexibility in logistics (Persson, 1991). Heuristic modeling allows for determining the ordering schedule of deteriorating products and variable demand by allowing for changes in order size and replenishment cycles (Bahari-Kashani, 1989). Selling price plays a significant role in determining the replenishment schedule for deteriorating products with time-dependent rates (Dye, 2007). Ordering schedules for large or box-store type retailers, such as Wal-Mart are based on dynamic pricing and market forecast to maximize profit (Pan et al., 2009). Each of these demonstrate the importance of scheduling in time-sensitive supply chains. However, many are not specific to perishable items and others focus on simple substitution strategies as a solution to scheduling shortcomings.

Perishable Healthcare Logistics

Logistics in the healthcare field affects every part of the world, whether through highly organized facilities with state-of-the-art technology or in small, third-world clinics employing limited services. Innovations in buyer-supplier relationships provides an alternative to outsourcing for logistics activities and actually improve the relationship among suppliers and hospitals (Su, Gammelgaard, and Yang, 2011). Also, healthcare delivery supply chains have experienced improvement through the implementation of cellular operations in material supplies and admission processes (Parnaby and Towill, 2009). Finally, multiple perspectives of pharmaceutical supply chains show constant shifts in how biopharmaceutical medications are purchased, distributed, and sold throughout the supply chain (Rossetti, Handfield, and Dooley, 2011).

Scheduling of Perishable Medical Supplies Logistics

In the medical field, perishable items include, but are not limited to items such as blood, organs, and vaccinations, where products have to be properly stored and often have a very limited shelf life.

Furthermore, these items rarely can be substituted in cases of scheduling errors or other stockout situations. Another unique nature of these types of items is biosafety concerns when handling these materials and needs to be addressed within companies and across the supply chain for safe delivery and handling (CDC, 2013). Blood ordering strategies is one area of the scheduling problem where extensive literature exists. In the medical field from transfusion to surgeries, several models have been developed to prevent over-ordering (Gupta, Kumar, and Diwan, 2003; Vibhute, Kamath, and Shetty, 2003) and to promote proper protocol for procurement (Morritt et al., 2005; Palmer et al., 2003; Bashawri, 2002). While the CDC maintains responsibility for the surveillance, detection, and warning of any potential risks regarding the public blood supply, multiple supply chains are involved in the scheduling, ordering, and delivery of these products to facilities with the highest quality possible. Purchasing perishable goods in anticipation of customer demand has been found to be a better practice than investment buying in portions of the perishable, medical supply chain (Sandelands, 1994). The Immunization Safety Office (ISO) collaborates with the federal, state, and local health agencies to administer and plan for emergency situations regarding vaccination information (CDC, 2013). Genuine partnerships of shared information with knowledge of operations and motivations can overcome conflict and allow for quick response of perishable items (Whiteoak, 1994; Hartmann and De Grahl, 2012). However, while the theory provides possible solutions to the challenges, in practice there remains a disconnect in the logistics scheduling of perishable biopharmaceuticals and needed service levels.

A severe problem presented in the healthcare field is the scheduling of perishable biopharmaceuticals. Often facilities store a small amount of medicine, such as vaccinations, blood pressure medicine, insulin, and cholesterol medicine for disbursing among patients for a short time. Usually an estimated five-day supply is kept within the building walls for normal daily use (CDC, 2013). When any type of crisis occurs that can disrupt the supply

chain or dramatically impact demand, the small supply of products is quickly depleted, and a lag time between ordering, delivering, and ultimately administering these products to patients occurs causing a disruption in the supply network management (Tatham and Pettit, 2010). A shortage in supply due to any type of supply chain disruptions has been seen to cause problems within the healthcare field with severe consequences to the medical facility and to the patient (Richey, Kovacs, and Spens, 2009; Hale and Moberg, 2005). Therefore, the specific policies and procedures in the healthcare industry further hinder just-in-time systems of healthcare logistics systems and ultimately impede product quantity and service in the industry (Jarrett, 1998).

The technology of time temperature integrators (TTI) has been used to improve the process. For example, the Defense Logistics Agency includes TTIs with every shipment of the flu vaccine as they move across the globe. The goal is to ensure the safety and quality of temperature sensitive products but can vary greatly depending on the product used (Sahin et al., 2007). Another related consideration is the amount and type of storage space, as these factors have an impact on both routing and inventory decisions involving perishable biopharmaceutical products (Stacey, Natarajarathinam, and Sox, 2007). Next, deterioration of perishable goods is a key parameter in the quantity ordered as well as the preservation methods or storage areas utilized (Verbic, 2006). Large supermarkets have implemented automated store ordering (ASO) systems to improve the efficiency and quality of the perishable line items held in inventory, inventory replenishment, and to reduce the amount of deteriorated items, excess inventory, and lower inventory holding costs (Van Donselaar et al., 2006). Finally, Yan and Wang (2013) built on the large retailer results and developed a continuous inventory model to allow retailers of seasonal perishable goods over a finite period of time to maximize expected profit through optimal ordering quantities and pricing.

The overall results of the literature search indicate that multiple models and frameworks have been

developed and evaluated regarding perishable products. However, none capture the issue faced in the medical field of not only perishable biopharmaceuticals but also that of limited and seasonal supply with fluctuating demand and constantly changing products and factors that affect the production of those products. The following section further develops this problem using flu vaccinations as the primary example. However, it should be noted, that this challenge can be applied to other types of vaccines and perishable products. For example, an unscheduled deployment of a large number of soldiers to an area requiring vaccinations or emergency movement of first responders to a hurricane event in certain foreign countries.

Example: Flu Vaccination Scheduling

The following example provides greater insight into the situation faced with the disconnect in the logistics scheduling of order and delivery of bioperishable materials in the medical field and across the supply chains involved. To emphasize the gap in literature regarding this matter, the example of flu vaccinations has been used to bring better understanding and knowledge to a situation that affects a large number of people and continues to spread throughout the world (CDC, 2013).

Vaccinations are a specialized area of healthcare that needs to be planned properly in order to provide appropriate care to the total population. This includes the subgroups of children's vaccinations, vaccinations needed for adults as they are exposed to various diseases, and as depicted in this paper, flu vaccinations that affect everyone. During the 2012-2013 flu season, 54.9% of children and 35.1% of adults were vaccinated in the United States, and there were approximately 200,000 people hospitalized for the flu and approximately 36,000 deaths (CDC, 2013). Chick, Mamani, and Simchi-Levi (2008) show that a cost-sharing contract between buyers at the government level and vaccine manufacturers provides incentives to improve optimization within the supply chain and thus the supply of flu vaccinations. Optimizing supply can reduce the number of affected individuals from this virus.

The scheduling of orders and deliveries of flu vaccinations is an annual problem that must take multiple factors into account (Nahmias, 1982). The first is determining the severity of the flu season based on the previous year data. If it was mild, patients are less inclined to get a flu shot and providers are less inclined to order additional medicine. However, if the flu season turns out to be severe, flu vaccinations will be depleted. Although medical providers can order additional flu vaccinations, there are very few companies who make the vaccination after the initial pre-order (CDC, 2013). Also, due to the pre-orders being placed from January to May, these companies only make a certain amount of medicine for that season and deliver the vaccinations beginning in July through November (CDC, 2013). If the flu season is extreme that specific year, these companies will run out of vaccinations if additional, late orders are placed. As an example of the scale of the challenge, during the 2012-2013 flu season, six manufacturers provided approximately 145 million doses of the flu vaccination in the United States (CDC, 2013).

To help answer the previous challenges, three research laboratories study the flu virus: Division of Intramural Research (DIR), Division of Clinical Research (DCR), and Vaccine Research Center (VRC) (NIH, 2013). These organizations also have to identify what modifications will be made to the vaccine each year. The introduction of new flu vaccinations for a varying virus creates bottlenecks in the supply of the vaccination and thus reduces availability to the population (Assi et al., 2012).

According to the CDC, the best way to prevent getting the flu is by getting a flu vaccination. There are two types of flu vaccines – flu shots containing a killed virus and nasal spray flu vaccines contained a live but weakened flu virus – and take approximately two weeks for the body to develop antibodies (CDC, 2013). These vaccinations are designed to protect the individual from the expected three most common strains expected that flu season. The goal is to reduce the overall impact of the flu on the population as a whole each year while helping the individual customer by decreasing his likelihood of becoming ill.

Facilities that provide flu shots are constantly competing with other facilities, such as Wal-Mart, Walgreens, CVS, Kroger, and private practice physicians. Often facilities under-order due to the increased competition and the risk of high cost, leftover vaccinations that have a very short shelf life (Tersine and Toelle, 1984; Toelle and Tersine, 1989). Prior to growth of other facilities being able to order vaccinations (i.e., drug stores, pharmacies, box stores, etc.), private practice facilities would schedule vaccinations with various local businesses, such as Peterbilt, Safety Kleen, etc. to provide vaccinations to the employees. Now in many cases and due to the shift in how and where flu vaccinations are administered, traditional medical providers are cutting their orders from 5,000 vaccinations to 1,000-1,500 vaccinations. Given the competition and cost of deterioration of unused stock, these challenges exacerbate an already difficult situation. Flu shots are only minimally profitable but are an important vaccination that is encouraged every year. Approximately 36,000 people died in one recent year from the flu in the United States (CDC, 2013). The increased challenges of vaccine supply and increased competition of allowing additional facilities to provide flu vaccinations creates a dilemma that may have actually reduced overall health. The questions become: have people receiving flu vaccinations increased? Has the death toll of people from the flu declined? And the big question is while more facilities are offering flu vaccinations, is there actually more supply? If so, then why does the system stockout and why are facilities reducing the amount ordered? While these problems would take much more research to answer, the scheduling of these flu vaccinations is extremely important to determine how and when orders need to occur in order to maximize coverage, optimize supply, and decrease the number of individuals affected by the flu virus.

RESEARCH QUESTIONS

The example of the flu vaccine demonstrates the tradeoffs that exists within this supply chain. The assumption would be that additional providers would increase the total number of vaccines administered each year. However, the increased

competition coupled with the time sensitive and perishable product create a unique problem. The already tight profit margins are further constrained with increased competition leading to a reduction in order size to mitigate holding costs and risks. Therefore, the question becomes is the current supply chain actually creating a form of destructive competition that ultimately hurts the national and individuals' health. This leads to the first set of research propositions.

- P1: The changing nature of the medical supply chain is increasing the number of outlets for perishable, time sensitive vaccines.
- P2: Medical suppliers are carrying less specific vaccines due to carry costs and risks.
- P3: The net effect is a reduction in the overall system (national) number of vaccinations due to the changes.

These basic research questions frame the overall examination of the impact of the changing nature of the perishable, time sensitive vaccine supply chain. It is necessary to determine if there is a major issue. Regardless, the literature identified a gap in the research for this type of medical materials. This leads to a second set of research items that should be examined.

- P4: All medical providers would benefit from increased forecast model accuracy of bio-perishable materials.
- P5: Improved bio-perishable material forecasting would reduce provider costs, increase profitability and increase service levels to customers.
- P6: The overall impact of an improved model would be an increase in the overall or national health due to higher fulfillment rates.

CONCLUSION

This paper differs from other investigations in the literature in that it identifies exhaustively and qualitatively the gap in academic literature, in logistics scheduling of product ordering and delivery, specifi-

cally with perishable biopharmaceuticals, and gives perspective for the need of quantitative models to assess this gap. The information available shows that scheduling is an extremely important topic in businesses and throughout the supply chain. As businesses continue to grow and the world becomes smaller through the use of communication and information technology, competition continues to rise as competitive advantage is sought. The need for logistics scheduling of products is a necessary step to obtain such goals.

The majority of the literature available that addresses logistics scheduling focuses on transportation, people, and machinery. While this is a very important topic for firms and supply chains, it does not address the specific needs of the logistics schedule pertaining to ordering and delivery of individual products, such as perishable biopharmaceuticals. This paper provides a contribution to the body of knowledge by identifying this gap in academic literature.

This is an initial step in exposing a gap in academic and professional literature and a mere stepping stone in the development of a framework for the logistics scheduling of the order and delivery methods used for perishable medical supplies. While this research did provide an extensive literature review, the scope is limited. Limitations in this research include highlighting the top business journals for information regarding logistics, logistic management, and logistics scheduling and searching the operations management field for the mathematical models that have developed to address scheduling of transportation, people, and machines. An opportunity would be to expand the literature review to medical journals using the same search terms. The literature review is extensive but can be further expanded to develop qualitative and quantitative research to incorporate into a theoretical model that can be utilized to begin filling this gap in literature regarding perishable medical supplies.

The next step to provide a more complete analysis of logistics scheduling in the area of ordering and delivery of flu vaccinations, and additional research needs to be conducted. First, a theoretical frame-

work needs to be developed and empirically tested to fill the gap identified in this article. While a single overarching solution to the gap may be unrealistic at this point, a model could focus on a particular product or possibly a supply chain of a specific product or group of products as a starting point. Second, it would be of great interest to focus on a specific industry, such as concentrating on humanitarian organizations where process modeling and optimization are still in the early stages of development (Blecken, 2010). Third, future examination of the relative importance of logistics scheduling would be of great interest to analyze the effects of this topic on a firm and the entire supply chain. The overall impact to the supply chain would be to analyze the effects of logistics scheduling not only on an individual product, such as flu vaccinations, but across the entire supply. This article presents an examination to begin the process addressing various healthcare concerns and logistics scheduling challenges in various situations: a crisis situation, a shortage in supplies, a natural disaster, or the annual challenges of vaccine distribution.

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