UNIVERSITY OF WISCONSIN, PLATTEVILLE

UNITED STATES OF AMERICA

The attached educational project, by Andrew Flick, entitled Intermodal Transport in Emerging Supply Chains: United States and European Union Perspective, when completed, is to be submitted to the Graduate Faculty of the University of Wisconsin- Platteville in partial fulfillment of the requirements for the (MASTER OF SCIENCE IN INTEGRATED SUPPLY CHAIN MANAGEMENT) degree.

Approved: Mary R. Bartling Date: 5/16/2018

Project Advisor

Professor Mary R. Bartling

Suggested content descriptor keywords:

Intermodal Transport, Logistics Networks, Emerging Supply Chains

# INTERMODAL TRANSPORT IN EMERGING SUPPLY CHAINS: UNITED STATES AND EUROPEAN UNION PERSPECTIVE

A Paper

Submitted to the Graduate Faculty of

the

University of Wisconsin, Platteville By

Andrew Flick

in Partial Fulfillment for the Degree of

MASTER OF SCIENCE IN INTEGRATED SUPPLY CHAIN MANAGEMENT

Year of Graduation: May 2018

**Abstract**

In recent decades, the rapid development of e-commerce, economic globalization, outsourcing, and increased environmental awareness, have been placing particular emphasis on developing and operating responsive, high-performance, and sustainable supply chains. As an integral part of supply chain management, the physical movement of goods between various nodes in the supply chain relies upon effective freight transport and logistics systems. For that reason, continuous improvement, ongoing development, and innovation in such systems is critical to enabling efficient and flexible value chains capable of meeting future requirements.

Emerging trends in global supply chain management, such as geographic expansion of distribution networks, hub and spoke models, as well as smaller and more frequent consignments, demonstrate the relevance of intermodal freight transport in enabling flexible, high-capacity transport and logistics networks (Zografos & Regan, 2004). Research on the topic suggest that intermodal transport is well positioned to be the driving force behind the next generation of freight transport systems, capable of meeting the challenges of emerging supply chains in an efficient and environmentally sustainable manner (DeWitt & Clinger, 2000; Simina, Patrick & Radu, 2009). Key advantages of the intermodal freight transport sector will be examined along with recent trends and developments, and existing challenges to future growth and importance of intermodal transportation in the United States and the European Union.

**Table of Contents**

## Introduction

According to Council of Supply Chain Management Professionals (2018), "logistics management is a 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 customer requirements" (para. 5). In turn, freight transportation is an integral part of logistics management, that represents the physical movement of goods between various nodes along the supply chain (Murphy & Knemeyer, 2015). Freight transportation networks play an increasingly important role in enabling economic growth and development through cost-effective and efficient movement of goods from production to consumption. The European Commission (2015) highlights the vital nature of freight transportation networks and considers transportation logistics a dynamic system that enables and powers increasingly complex and global supply chains to meet changing requirements for production and consumption of goods and services. The vital nature and role of freight transportation is also evident in the United States, a country that pioneered one of the most efficient road networks in the world through the completion of the Interstate Highway System, commissioned in 1956 and designed to connect the country through 47,000 miles of high-speed roadway (Hale, 2006). The development of an effective transportation network in the United States had a tremendous effect on the overall economic and industrial composition of country. This major project led to a significant reduction in trade barriers between US states, major metropolitan areas, and rural communities, connected the United States to major trade routes in Mexico and Canada (Michaels, 2008).

The formation of the European Union in the early 1990s and the focus on removing trade barriers within the economic union continue to guide policy decisions across European capitals.

The European Union clearly recognizes efficient logistics and transportation sectors as a prerequisite to continued economic growth and progress as well as the need to continue supporting the development of a frictionless flow of goods throughout the economic union (European Commission, 2015).

The United States and the European Union place in the top 3 largest markets in terms of overall logistics and freight transportation spend with $1.5 trillion and €960 billion respectively (Kille, Schwemmer & Reichenauer, 2015). Parallels can also be drawn between the various factors impacting and shaping the growth and development of the respective logistics sectors, such as market liberalization initiatives, transition from manufacturing to largely service economies, and proliferation of offshoring and outsourcing practices; which create longer and more complex supply chains as a result. Despite similarities that exist between the logistics and freight transportation sectors in the United States and the European Union, these markets have also been subject to unique and distinct challenges that have been shaping their development and likely to continue to influence future direction, policy making, and investment (European Commission, 2015).

The United States and the European Union freight transportation markets operate in a largely free-market, deregulated environment with similar levels of logistics infrastructure, service performance, and competition. According to the World Bank (2016), the United States ranks number 10 on its Logistics Performance Index (LPI), which is a comprehensive measure of the efficiency of international supply chains. Seven other countries in the top 10 of the Logistics Performance Index are members of the European Union, including Germany, Luxembourg, Sweden, Netherlands, Belgium, Austria, and the UK (World Bank, 2016). It is possible to generalize that the United States and the European Union freight transportation and logistics

sectors can be characterized by a similar quality of infrastructure, levels of technology, and sector investments. It is important to note that the demand and provision of logistical services in the United States and the European Union are influenced by the socio-economic and technological environments, which generally drive freight transport requirements. These requirements in turn provide input into the development of freight transport networks designed to support economic activities (Zografos & Regan, 2004). It becomes possible and beneficial to expand the geographic scope of the study to encompass not only the United States, but also the European Union.

Having established the role of effective freight transportation and logistics systems in enabling economic growth, development, and competitive position in the global marketplace, it becomes clear that increasing the capabilities and performance of such systems is of paramount importance to competing supply chains and national economies around the world. Stakeholders at various levels, including policy makers, have been dedicating resources to understanding, planning, and designing effective transportation and logistics networks capable of supporting the requirements of emerging supply chains. For instance, the European Union has commissioned a number of studies and reports aimed at understanding the current challenges, solutions, and policies necessary to support the development of EU-wide freight transportation and logistics strategy (European Commission, 2015).

Research suggests that the concept of intermodality, which is one of the core characteristics of intermodal freight transport, is poised to be the driving force behind the development of effective and highly efficient transport and logistics operations (Zografos & Regan, 2003). The benefits of intermodal transport, such as flexibility, sustainability, and cost advantage over road transport, have been widely recognized and have been driving the adoption

and growth of this transport sector in general. Zografos and Regan (2003) note that the role of intermodal transport networks in the world economy has been elevated, as a result of environmental and quality of life concerns, the evolving nature of modern supply chain requirements, and rapid advancement of information and communication technologies. DeWitt & Clinger (2000) see intermodal freight transportation as a critical element in the evolution of freight transportation networks and central to the success of competing supply chains of the future. Yet, some significant challenges for the continued growth and adoption of intermodal transportation networks are present, such as the ability of intermodal transport configurations to meet the flexibility and speed of information required by the technology-enabled businesses (Zografos & Regan, 2003). In addition, issues surrounding sufficient intermodal transport capacity have also been identified, which have special considerations in the European Union, with policies limiting the length of freight trains and prioritization of passenger movements over transport of cargo (Clausen & Voll, 2013).

**Statement of the Problem**

In the twenty first century, organizations increasingly recognize supply chain excellence as a competitive advantage in a global and demand driven environment, where customer satisfaction is directly linked to business results (Mentzer, Myers, & Stank, 2007). As supply chains become more extensive and complex, the need for highly effective, efficient, and flexible freight transport networks able to continuously adapt to the changing business, political, and environmental requirements is heightened.

While modern transport modes have undergone significant change and development and are currently available at the disposal of supply chain and logistics managers, emerging supply chains demand a level of flexibility and integration that separate modes of transport are not in the

position to fully support (DeWitt & Clinger, 2000). Existing research suggest that intermodal transport is uniquely positioned to play a critical role in the development of emerging high-performance freight transport and logistics networks. This research paper attempts to consolidate existing literature on the topic and outline emerging trends and challenges to the continued growth and development of intermodal transport networks in the United States and the European Union.

**Purpose of the Study**

This research paper will explore and analyze the emerging role of intermodalism and intermodal transport in the development of effective and highly efficient freight transportation and logistics networks. Such networks are required to meet the changing requirements of modern supply chains, continued globalization, and evolving attitudes toward the importance of a sustainable transportation system in the United States and the European Union.

This study will provide a comprehensive definition of the intermodal concept in commercial freight transportation, review its historical development, economic impact, as well as current trends and future considerations. Factors that had a significant impact on the development of intermodal segment, such as the advent of containerization, transportation industry deregulation, and increasing global trade as a result of globalization, are discussed to explain the strong position of intermodal transport in transport and logistics networks of the future.

The outcomes of this research work will review the changing requirements in supply chain distribution systems and challenges they create for existing freight transportation and logistics systems. The paper will then make an argument that given sufficient policy attention

and investment, intermodal freight transport is in a strong position to meet emerging supply chain challenges and of specific relevance to the emerging business and logistical environments.

**Significance of the Study**

The outcome of this paper is expected to provide a well-rounded review of the intermodal transport system in the United States and the European Union, as well as a discussion on the emerging role of intermodal transport in modern and evolving supply chains. The content of the research paper can be used to gain a basic understanding of the principles behind intermodal transport and its development path starting in the 1950s. More importantly, characteristics that make intermodal transport a suitable solution in the time of rapidly changing technology and supply chain requirements will be discussed and highlighted.

**Methodology**

The research paper will examine existing academic research, professional journals, publications, and related literature to support the objectives and purpose of the study. Specifically, existing academic literature providing the background and context for the development of logistics and intermodal freight transportation sector in the European market will be reviewed. Multiple publications from the European Commission will be used for much of the reviewed data and statistics on the state of the European transport sector as well as current and emerging policies. In addition, the discussion section of the paper will contain insights based on personal experience in the logistics sector in the United States and the European Union, as well as insights from other transportation professionals on both sides of the Atlantic.

## Literature Review

The decision to explore intermodal transportation is often based on the realization that a single mode of transportation is not always ideal to meet specific needs and requirements of an

organization. In many cases, deliveries simply cannot be completed using just one mode of transport due to availability, cost, or capability considerations (APICS, 2011). Therefore, intermodal service enables organizations to improve their distribution capabilities, increase flexibility and efficiency, while reducing costs and, increasingly important, environmental emissions from transport operations.

Intermodal transportation refers to the transport of cargo in the same loading unit or container using two or more modes of transportation without needing to reload the cargo. Extending the definition to a transport system, intermodality is a concept of combining multiple modes of transport to produce a seamless door-to-door service and overcome the limitations of any single mode of transport (Profir, 2011). A transport system is designed to maximize the advantages of each mode, while at the same time minimizing its disadvantages (Murphy & Kneymeyer, 2015). Profir (2011) also notes that economic advantages of intermodal transport for supply chains participants include flexibility of designing a distribution network to meet specific needs of the partners, increased transport safety, reduction in transportation costs, as well as decreased congestion on public roads and highways. In recent years, environmental objectives and policies have also been driving further adoption and conversion of road freight to intermodal combinations of road, rail, and water modes, as these configurations are considered to be more environmentally sustainable (Stinga, 2014).

**Emergence of Intermodalism**

In North America, the early signs of modern intermodalism began to emerge with the introduction of trailer on flatcar (TOFC) rail service in the 1950s (APICS, 2011). TOFC or “piggyback” service enables the transport of truck trailers on top of train flat cars, utilizing much of the existing rail infrastructure. Such transport configurations pair the low cost and efficiency

of rail transport over long distances, with flexibility and speed of local pick-up and delivery by truck. Major North American railroads invested heavily into the development of TOFC services to complete with over the road transportation (Slack, 1990). While the introduction of TOFC service was an important step toward development and adoption of intermodal transport, it achieved limited success with shippers and railroads. Slack (1990) points out that TOFC service relied on ramps to drive trailers onto individual flat cars, which took time to deliver and assemble, resulting in an overall slow and inefficient operation. By the end of the 1970s TOFC volumes accounted for less than 1% of total freight movements in the United States and developed a reputation as a slow and unreliable service option (Slack, 1990).

The significant breakthrough for intermodal transportation in North America, specifically in the United States, was the period of deregulation in the transportation industry, which changed much of the commercial transportation industry in the last three decades of the twentieth century (Donovan, 2000). Slack (1990) points out that the Shipping Act of 1984 made possible official filing of intermodal tariffs and enabled intermodal mergers. Prior to this, little competition across different modes of transportation was possible in the United States as different modes of transportation were regulated by separate government bodies and mergers across modes were not permitted. Donovan (2000) notes that, with containerization holding significant promise for the shipping community, it was time to start comparing costs across different modes of transportation and the new regulatory platform made possible the formation of companies seeking to capture increased efficiencies and reduced cost of transportation. During this time, much of the development in surface intermodal services, most notably in truck-rail, was being driven by the ocean shipping lines seeking to extend their services into the interior of the United States. Famously, the introduction of double stacking containers on flat cars (COFC) in the early

1980s by Sea-Land and American Presidential Lines (APL) were credited with revolutionizing of intermodal transport in the United States (Slack, 1990). Such developments sparked fundamental shifts in intermodal transport in the United States. Initially, COFC services primarily targeted import/export trade via the West Coast ports, but soon encountered an issue of imbalanced West to East flow of containers, which prompted operators to offer attractive rates for westbound domestic cargo in ocean containers, giving rise to modern domestic container business (Slack, 1990). Today, intermodal network in North America has extensive reach and connects major maritime ports with inland hubs and facilities designed for efficient handling of containerized import/export as well as domestic rail cargo (Intermodal Association of North America, 2018).

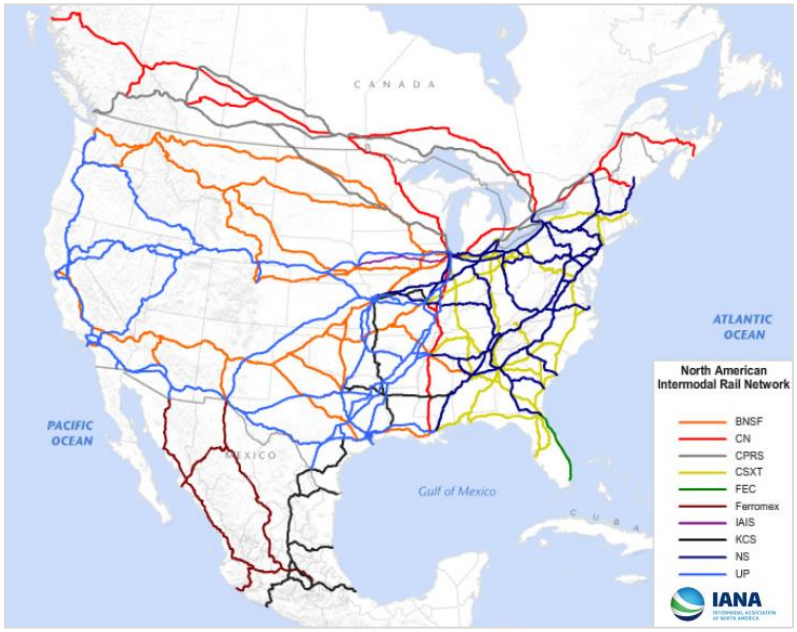


*Figure 1: North American Intermodal Rail Network*

**Containerization**

One of the fundamental characteristics of intermodal transport is the use of a single loading unit during transport, which first began in the 1960s with the introduction of containers that closely resembled truck trailers (Donovan, 2000). However, the concept of utilizing multiple

means of transport has been in existence long before modern containers, as barrels, bags, and boxes of all shapes and sizes were trans loaded between road vehicles, ships, and trains to move goods between the point of origin and the point of destination. Donovan (2000) explains that before the introduction of standardized containers, this process had been incredibly laborious, inefficient, and achieved limited mechanization. In this sense, the introduction of standardized containers did not give birth to intermodal transportation, but instead transformed and accelerated its use, development, and market adoption as a flexible and cost-effective way of moving goods to market. The introduction of standardized containers in the 1960s had a profound impact on the maritime industry, leading to significant growth in global trade and transport volumes (Slack, 1990). Murphy & Knemeyer (2015) credit containerization with dramatic reductions in freight handling costs and increased efficiencies of intermodal transport operations. Introduction of such standard loading units enabled a myriad of intermodal possibilities, "because the container is interchangeable among rail, truck, and water carriers, containers can be used in intermodal applications and provide the advantages offered by each of several modes" (Murphy & Knemeyer, 2015, p.218). Profir (2011) also emphasizes the significance of containerization in the development of intermodal transport by asserting that the use of standardized loading units provides greater protection and security, especially for high-value goods, while also enabling efficient handling and transshipment of cargo from one mode to another in the transportation process. In this regard, containerized transport can be viewed as a component of a larger intermodal transport system with its specific technical and economic benefits (Profir, 2011):

- Containerization enables a multitude of goods and product categories to be transported via multiple modes of transportation

- Complex movements of freight without requiring intermediate trans loading (loading/unloading) operations reducing the likelihood of damage or loss of product during transportation
- Enclosed and rigid configuration of shipping containers enhances cargo security while in transportation and during waiting periods at various point in the transport network
- Significant reduction in required handing activities as cargo moves between different modes of transport, which also leads to reduced freight costs

The benefits of standardized containers were further enhanced by introduction of different container sizes, commonly ranging from 20', 40', and 45' for ocean containers to 48' and 53' domestic containers prevalent in the North American market. Furthermore, specialized container types also became available, addressing the needs of shippers with temperature-controlled and liquid bulk cargo (Murphy & Knemeyer, 2015).

**Service Configurations**

The introduction and rapid proliferation of containers in ocean shipping in the 1960s led to the development of intermodal configurations, where part of the transport is completed by water carriage. Such intermodal service can accommodate a truck trailer, a railroad car, or a container that spends part of the journey aboard an ocean-going vessel or river barge (APICS, 2011). Intermodal configurations that include water transport are most prominent in global maritime trade, but also have local and regional applications transporting freight through the rivers, coastal waterways, and canals (APICS, 2011). Murphy & Knemeyer (2015) point out the development of "land bridge" services, which introduce a surface transportation leg (via rail or truck) in an otherwise port to port all-water route. Such intermodal configuration is designed to provide an option to reduce overall transit time between origin and destination points, while still

maintaining cost advantage over the next fastest mode of transport - air freight. In addition to the core intermodal configurations of truck-rail, truck-air, and truck-water, a number of other and, sometimes more complex, service configurations are possible, as outlined in *Figure 2* by the Intermodal Association of North America (2018).

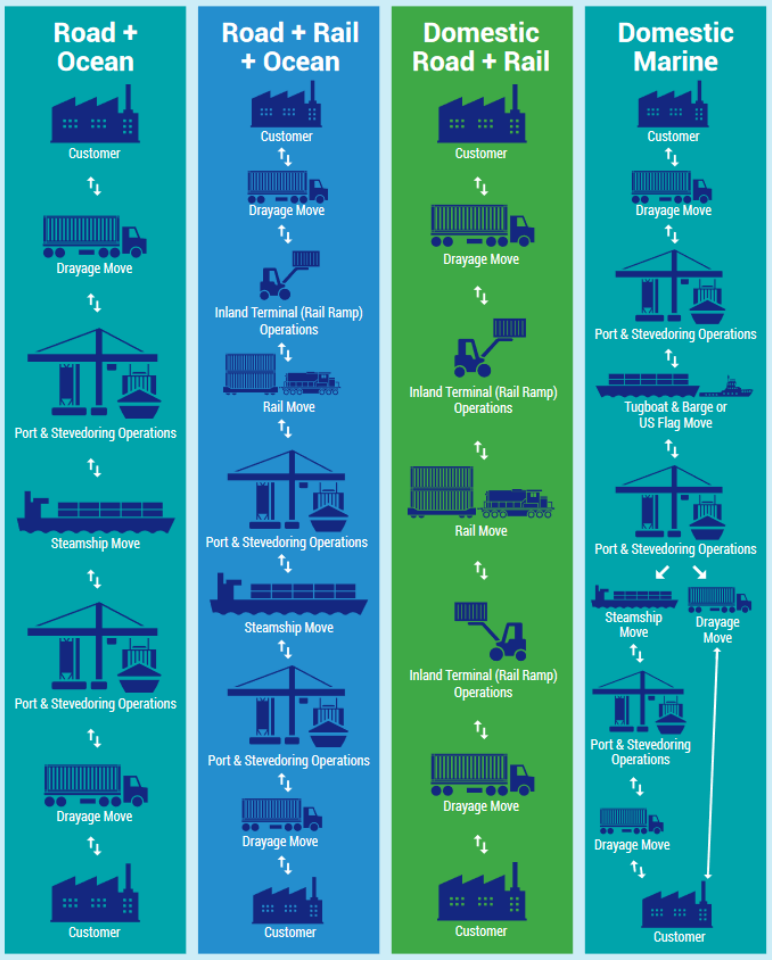


*Figure 2 Intermodal Service Configurations*

In North America, the concept of intermodal transport, as it relates to freight transportation, has traditionally been associated with containerized truck-rail and truck-water services. However, it is important to note that other successful intermodal transport configurations exist, including non-containerized options, which continue to serve as an indispensable means of moving freight from the point of production or distribution to the point

of consumption. DeWitt and Clinger (2000) discuss that some bulk commodities, such as grain or fertilizer, can move by truck before connecting to rail or water service. One of the most prominent and critical modes of transportation for high-value and time-sensitive cargo is air transport, which relies on a network of commercial airports and airstrips for line haul movement of cargo. Since most shippers and consignees are not located at airports and do not own private airstrips, some intermediary mode of transport is required for pick-up and delivery of cargo to and from air transport facilities (APICS, 2011). DeWitt and Clinger (2000) concur that inherently all express air shipments are intermodal as road links at origin and destination are required to connect to line haul service by air. Some of the prominent examples of truck-air service are express parcel operators such as UPS and FedEx that specialize in the door-to-door movements of small but time-sensitive cargo.

Intermodal truck-air service has experienced significant development and growth from the advent of e-commerce and growing adoption of lean principles by shippers (APICS, 2011). Thus, it is important to understand the full scope of intermodal service configurations as all single bill, containerized and non-containerized, multimodal movements. Such expanded definition, in contrast to more traditionally defined truck-rail and truck-water services, can help to highlight the importance and expanded opportunities intermodal freight transport networks hold.

**Impact and Recent Developments**

A survey of existing literature shows that the emergence of intermodal transport via trailer on flat car (TOFC) services, supported by transportation industry deregulation and innovations such as containerization and double stacking, served as significant impetus to the development and growth of the intermodal transport segment in the United States. Much of this

growth came as a result of containerization and significant growth in global trade, as well as the development of domestic and ocean container services based on truck-rail configuration. In fact, according to the Intermodal Association of North America (2018), 10 largest carriers generate over $20 billion from intermodal operations, which represent 25% of the total US railroad revenues.

The shift toward service-based economy in the second half of the twentieth century in the United States and Europe has accelerated the change in cargo profile from raw materials and bulk commodities to consumer goods and products. Islam and Blinge (2015) note that in Europe rail freight transport lost significant ground to other modes of transportation, especially to road transport. In the 1970, one-third of the road-rail intermodal traffic in Europe was carried by national railways, compared to one-fifth just twenty years later. This came as a result of slow response to changing requirements of rail freight shippers and aggressive development of road trucking operations that offered flexibility, responsiveness, and overall higher-level of service (Islam & Eidhammer, 2017). European rail freight operations have since seen sweeping reforms initiated by the European Commission to increase competitiveness and attractiveness of rail freight transport (Islam & Blinge, 2015). US railroads have also been slow to respond to the growth in consumer goods market facilitated by containerized ocean transport, but have been gradually gaining ground. Zografos and Regan (2004) note that domestic intermodal transportation in the United States is on the rise and has been climbing at the rate of about 5% annually.

While the discussion of intermodal transport is frequently focused on truck-rail configurations, the importance of short-sea water transport, especially in the European freight market, cannot not be overlooked. Grosso, Lynce, Silla, and Vaggelas (2010) point out that the

development of short-sea shipping is high on the European Commission's agenda as an effective means of counteracting the dominance of road freight and advancing more sustainable and efficient intermodal transport solutions. Short-sea shipping is one of the most developed transport sectors in Europe due to the extensive use by the industrial manufacturing segment, but only about 25% of its volume by weight that can be fully integrated into intermodal networks. However, several projects are under way to improve short-sea capabilities in the context of intermodal transport solutions, including Trans-European Transport Network, which focuses on developing a multimodal network that ensures appropriate mode of transport for any freight movement in the European territory (Grosso, Lynce, Silla, & Vaggelas, 2010).

## Discussion

Modern supply chains can be characterized by relentless focus on customer satisfaction arising from heightened levels of global competition and cost pressure. Customer expectations increasingly include low cost, fast delivery, and reliable service; challenging existing supply chain structures and forcing companies to rethink existing approaches to freight transportation and logistics in order to meet customer requirements, while controlling costs. In addition, increased awareness of the impact from supply chain operations on the environment and public health have been putting pressure on organizations to optimize their processes, introduce sustainable solutions, and reduce the overall environmental footprint. Given that freight transport operations contribute to the organizations' emissions footprint in a significant way, intermodal transportation holds significant promise in pursuit of integrated and sustainable solutions capable of supporting supply chains focused on flexibility, speed, and reliable execution of transport and logistics operations.

**Changing Supply Chain Requirements**

The forces of globalization in the second half of the twentieth century, enabled by advancements in long distance freight transportation and information and communication technologies (ICT), continue to fuel the growth of global trade. Mentzer, Myers, and Stank (2007) point out that "globalization infers the cross-border movement of goods and the emergence of global competitors and opportunities across competing supply chains within an industry" (p. 2). Organizations took advantage of global opportunities by moving sourcing, production, and other activities to markets that offered superior access or cost considerations, thus expanding their geographic footprint and complexities of their supply chains.

Yet some of the same advancements, such as greater information availability and communication technologies, have been shifting the balance of power toward the customers or end users, fundamentally changing the environment in which modern supply chains must operate. DeWitt and Clinger (2000) predict that customers of the future will be dismissive of global sourcing, manufacturing, or freight transport issues, expecting a customized service at the right time, in the right place, and at the right price. Organizations increasingly find themselves operating in a business environment characterized by global competition, cost pressure, and growing expectations from customers and end users. Such operating conditions challenge the organizations' supply chains to become more efficient, less expensive, and flexible to adopt and evolve with customer tastes, preferences, and requirements. Responsible for the physical movement of goods and materials through the various nodes in the supply chain, logistics and transportation functions must also evolve to support the organizations' supply chain strategies and changing requirements.

Zographos and Regan (2003) highlight several important trends in global supply chain management that are expected to impact the development of freight transport and logistics networks:

- Geographical expansion of supply chain footprint and operations.

  As supply chains grow longer and become more complex, physical distances between the chain nodes are increasing correspondingly, requiring flexible freight transportation and logistics solutions that rely on multiple modes (road, water, air, and rail) to provide secure, competitive, and reliable service.
- Changes in size and functional nature of logistics infrastructure nodes.

  For instance, the advent of break-bulk and cross docking operations impacts the size and configuration of transportation and logistics networks required to support them.
- Smaller and more frequent consignments.

  Popularization of Just-in-Time (JIT), lean manufacturing principles, and continued growth in the e-commerce sector, continue to place increased importance on partial load, package, and last mile delivery services.
- Increase in vehicle utilization.

  High levels of vehicle capacity utilization are critical to enabling competitive, low cost service to customers through cost effective freight transport operations.
- Changing freight characteristics.

  The on-going transition from industrial to service-oriented economy in the developed nations change the cargo profile and emphasize the need for a fast and high-capacity freight transportation system.

The "systems approach" to intermodal transport networks and their ability to effectively combine multiple modes to meet specific needs of geographically dispersed supply chains, make the intermodal transport sector increasingly relevant in the development of freight transport and logistics networks capable of meeting the challenges outlined. Simina, Patrick, and Radu (2009) further underline the power behind multi-mode capabilities, explaining that intermodal networks are capable of combining the speed of air, low cost of water service, high capacity of rail, and flexibility of road service, in a configuration that makes the most sense for a given set of conditions and requirements.

**Supply Chain Security**

The issue of supply chain security represents additional consideration for the development and growth of intermodal freight transport. Heightened security concerns in the aftermath of the September 11, 2001 terrorist attacks on the United States have steadily increased the emphasis on supply chain security, both from governmental policy and private sector perspectives. The United States government has introduced several programs targeted toward more effectively managing security risks arising from international trade, such as Customs Trade Partnership and Against Terrorism (CTPAT) and Container Security Initiative (CSI) (Zographos & Regan, 2003). Companies too began to pay closer attention to their supply chain security practices and those of their partners and vendors. Mentzer, Myers, and Stank (2007) point out that carrier security practices began to play a greater role in shipper's carrier sourcing and selection decisions. The authors continue that supply chains have multiple potential points of vulnerability with transportation being one of the greatest challenges, as it has a greater risk of exposure due to long distances and limited control over the operating environment (Mentzer, Myers, & Stank, 2007).

In the case of international freight transportation, these vulnerabilities are particularly heightened as cargo can spend days or weeks in transit, crossing national borders, and dwelling at various points in the transport and logistics network, thus, potentially increasing opportunities for theft or tempering. In this respect, intermodal transportation presents a set of advantages as well as additional challenges that must be carefully managed. Tsamboulas (2010) notes that road and rail transport, otherwise considered surface modes, are more exposed to a possible attack, when compared to water and air transport. This is largely due to less stringent security measures and oversight in place for surface transportation. In addition, a combination of physical transport via multiple modes and nodes in the transportation network present added complexity to security challenges.

Not all intermodal cargo is transported in standardized containers. However, the Intermodal Association of North America (2018) estimates that close to 95% of the world's manufactured goods spend at least part of their journey to end users in a shipping container, which provides a universal handling unit between water, air, rail, and road transport modes. The rugged and durable nature of containers presents a physical obstacle to theft or tempering of cargo. Such characteristics of shipping containers strengthens the deterrence aspect, which according to Mentzer, Myers, and Stank (2007), is one of the key elements of a transportation security program. The deterrence aspect, coupled with secure transport methods such as double stacking of containers on freight trains, and supported by comprehensive transport network security measures, bears potential to improve the overall security profile of intermodal transport, compared to its single mode counterparts. Likewise, the improved handling and interchangeability of standardized intermodal containers leads to more rapid movement of cargo through various nodes in the supply chains, lessening the amount of dwell time and opportunities

for security risks to materialize. Unlike trucks that make regular stops in places accessible to the general public, such as truck stops and highway ramps, access to rail yards and ports is much more restricted, making it difficult to gain unauthorized access to cargo. Furthermore, an argument could be made that intermodal cargo is generally more secure in transit as well, as access to rail, water, and airways is more difficult to attain, in contrast to public roads and highways.

Significant innovations in information and communication technologies (ICT) have been introduced that further strengthen the security of intermodal transport. Tsamboulas (2010) notes that technologies, such as RFID applications that enable automatic container tracking and verification, as well as temper evident seals and electronic seals, can provide an early indication of compromised cargo and potential security threats.

**Globalization**

The growth of global trade experienced in the second half of the twentieth century, enabled by advancements in shipping and information technologies, is expected to continue at increasing rates. According to the World Trade Organization (2017), global trade in manufactured goods increased from $8 trillion in 2006 to $11 trillion in 2016, about 5% per year. Furthermore, near-term forecast calls for overall international trade to grow 3.6% in 2017 and 3.2% in 2018 (World Trade Organization, 2018). Such growth will continue to put pressure on existing supply chain links and supporting freight transportation and logistics networks. High levels of containerization in global trade provide secure and efficient means of moving cargo in the transport networks using multiple modes. Intermodal transport sector is uniquely positioned to accommodate containerized growth in world trade through efficient use of existing infrastructure and flexibility of modal combinations to maximize the advantages of each mode,

while limiting the impact of its disadvantages. Simina, Patrick, and Radu (2009) point out that intermodal transport sector, with improvements in information technology and network infrastructure, is considered the most effective way of handling international trade on a door-to-door basis.

As a result of activities associated with globalization, such as offshoring and global sourcing, supply chains have become longer and more complex, increasing the length of transport movements. Zografos and Regan (2003) further explain that spatial concentration of inventory and production, as well as advancements in information and communications technologies drive the formation of geographically dispersed logistics networks that require long-haul transportation services. Much of the demand for global freight transportation over long distances has been handled by the ocean shipping industry with as much as 95% of all manufactured products being containerized (Intermodal Association of North America, 2018). For that reason, it is possible to project that the forecasted growth in global trade will also translate into increases in containerized cargo, which in turn will drive the demand for intermodal transportation services to enable efficient and cost-effective door-to-door service customers have grown to expect.

**Sustainability**

In recent years, global supply chains have experienced increasing pressure from government regulators, consumer groups, and individuals around the world to reduce environmental footprint and introduce sustainable practices across its various functions, including transportation and logistics. Globally, transportation is estimated to be the second largest contributor and accounts for 23% of all carbon emissions (Iacob, Sinderen, Steenwijk, & Verkroost, 2013). Furthermore, Maciulis, Vasiliauskas, and Jakubauskas (2009) estimate that

close to 1% of European Union's GDP is lost to negative effects of growth in the transport services sector, primarily from urban congestion and pollution. Given that a significant portion of greenhouse gas emissions come from burning fuel during logistics and transport operations, there is a great deal of pressure on supply chains with large fuel consumption to become more efficient and find ways to improve their environmental performance.

Jorsfeld, Hvolby, and Nguyen (2016) argue that organizations' sustainability efforts must be focused on improving energy efficiency of their supply chain activities. Global manufacturing involves constant movement of inventory, often over long distances, which requires burning large amounts of fuel. The authors point out that up to 75% of a company's carbon footprint can be attributed to its logistics function and, therefore, on-going logistics operations represent an area of great potential for reducing fuel consumption, costs, and environmental impact (Jorsfeld, Hvolby, & Nguyen, 2016). Given the impact of freight transportation and logistics functions on the organization's emissions and environmental footprint, transportation network configurations capable of reducing this impact receive increasing attention.

US Department of Transportation (1998) state that intermodal transport "not only is rapid, reliable, customer-oriented, and efficient, but also makes effective use of the existing infrastructure and can help provide needed transport without undue environmental costs" (p.4). The European Commission also views intermodal transport as an efficient, environmentally friendly, and sustainable mobility solution, especially relevant for freight transportation (Simina, Patrick, & Radu, 2009). The main factors contributing to intermodal transport being characterized as sustainable and environmentally friendly are tied to efficiency in transporting large volumes of cargo, reducing road congestion, and generating less harmful emissions when compared to the more common road transport by truck. Simina, Patrick, and Radu (2009)

highlight these factors at work by stating that a “transport in single train of 20-25 swaps, in a single barge of 130-175 containers or in a single ship of 8,000 or more containers, replace the same number of trucks and leads to significant gains in the economy energy, personnel costs, vehicle maintenance and other costs that are considered internal and external” (p.85). One key advantage of intermodal transport is the capability to execute a portion or segment of the total movement, otherwise done by road, using a more environmentally sustainable mode, such as water or rail. For example, it is estimated that on average railroads in North America can move a ton of freight over 405 miles on a single gallon of diesel fuel, reducing greenhouse or CO2 emissions by two-thirds compared to road transport by truck (Russo, 2011). Such reduction in fuel consumption and associated emissions also comes with the benefits of alleviating traffic congestion in urban areas, reducing noise levels, traffic accidents, as well as wear and tear on public motorways. Industry research suggests that intermodal transport systems offer not only efficiency and cost competitiveness, but also the flexibility in selecting the most advantageous combination of modes for reduced fuel consumption, cost, and associated emissions (Bauer, Bektas, & Crainic, 2010).

## Conclusion

Starting in the 1950s as a way for US railroads to compete with road trucking for domestic freight, the concept of combining multiple modes of transportation as part of a single movement has taken a strong hold in the freight transportation industry and appears to be here to stay. In fact, according to the Intermodal Association of North America (2018), the United States intermodal freight market, estimated at $40 billion, has grown to be the largest in the world. From its humble beginnings as trailer on flatcar (TOFC) service, intermodalism has grown to encompass a host of configurations, service levels, and applications in the freight transportation

industry. Fueled by the introduction of a shipping container, deregulation in the transportation industry, and increasing global trade, intermodal transport has been evolving into a high-capacity, flexible, and environmentally sustainable system of transporting freight from production to consumption markets.

Advances in information and communication technology have opened new opportunities for organizations through outsourcing, offshoring, and access to global markets. These forces are also responsible for shifting the balance of power from manufacturers and retailers to end customers, creating a highly competitive global environment where supply chain excellence is a source of competitive advantage. In this respect, customer expectations have never been higher and the freight transportation and logistics networks that facilitate the physical movement of cargo are under pressure to perform and adapt to changing supply chains requirements. Zografos and Regan (2004) outline geographically distributed sources of supply, smaller and more frequent shipments, and increased service expectations as some examples. Globalization and continued growth of international trade will challenge existing infrastructure and supply chain practices to perform more efficiently and at a lower cost. In addition, the focus on environmental sustainability is going to continue to influence existing freight transport and logistics systems to develop solutions aimed at minimizing harmful emissions and other external costs, such as noise pollution and road congestion.

Emerging trends and challenges in global supply chains management outlined in this paper elevate the importance of intermodal transportation as a high-performance, efficient, and customer-oriented freight transport option capable of meeting increasing expectations in a cost-effective and sustainable manner. DeWitt and Clinger (2000) argue that several important innovations and developments, such as containerization in the second half of the 20$^{th}$ century and

focus on global supply chain management, position intermodal transport for continued growth and further integration with unimodal transportation options.

In addition to previously discussed advantages of intermodal transport, such as high capacity, security or cost competitiveness, its greatest strength lies in the ability to combine multiple modes of transportation in a single movement to leverage the advantages of each individual mode and achieve the cost, speed, and environmental objectives of the supply chain.

Intermodal transportation has seen significant growth and development in the United States and has received strong government support in the European Union, being promoted as a sustainable solution to the negative impacts of freight transport (Simina, Patrick, & Radu, 2009). Continued focus on innovation, development, and infrastructure improvements in the intermodal sector holds promise to position intermodal transport at the heart of the next generation of freight transport and logistics systems capable of meeting supply chain challenges in an efficient and cost-effective manner without compromising the environment or quality of life of the stakeholders it intends to benefit.

## References

APICS The Association for Operations Management. (2011). *APICS Certified Supply Chain Professional (Version 2.2, 2011 ed.).* Chicago, IL: APICS.

Bauer, J., Bektas, T., & Crainic, T.G. (2010). Minimizing greenhouse gas emissions in intermodal freight transport: An application to rail service design. *The Journal of the Operational Research Society 61*(3), 530-542.

Chen, L. & Miller-Hooks, E. (2012). Resilience: An indicator of recovery capability in intermodal freight transport. *Transportation Science 46*(1), 109-123.

Council of Supply Chain Management Professionals (2018). *CSCMP Supply Chain Management Definitions and Glossary*. Retrieved https://cscmp.org/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms.aspx?hkey=60879588-f65f-4ab5-8c4b-6878815ef921

Clausen, U. & Voll, R. (2013). A comparison of North American and European railway systems. *European Transport Research Review 5*(3), 129-133.

DeWitt, W. & Clinger, J. (2000). *Intermodal Freight Transportation*. Retrieved from Transportation Research Board website http://onlinepubs.trb.org/onlinepubs/millennium/00061.pdf

Donovan A. (2000). Intermodal transportation in historical perspective. *Transportation Law Journal 27*(3), 317.

European Commission (2015). *Fact-finding studies in support of the development of an EU strategy for freight transport logistics Lot 1: analysis of the EU logistics sector*. Retrieved from https://ec.europa.eu/transport/sites/transport/files/themes/strategies/studies/doc/2015-01-freight-logistics-lot1-logistics-sector.pdf

European Council of Applied Engineering (2001). *Freight Logistics and Transport Systems in Europe*. Paris: Euro-CASE.

Grosso, M., Lynce, A., Silla, A., & Vaggelas, G.K. (2010). Short Sea Shipping, intermodality and parameters influencing pricing policies: the Mediterranean case. *Netnomics: Economic Research and Electronic Networking 11*(1), 47-67.

Hale, T. (2016). Interstate highway turns 50. *Construction Digest 81*(12), 6.

Intermodal Association of North America (2018). *Intermodal Fact Sheet*. Retrieved from http://intermodal.org/sites/default/files/documents/2018-01/IntermodalFactSheet.pdf

Islam, D. & Eidhammer, O. (2016). Advances in the competitiveness of pan- European rail freight services: findings from a case study. *R&D Management 46*(4), 761-780.

Islam, D. & Blinge, M. (2017). The future of European rail freight transport and logistics. *European Transport Research Review 9*(1), 1-2.

Jorsfeld, L. M., Hvolby, H.H., & Nguyen V.T. (2016). Implementing environmental sustainability in logistics operations: a case study. *Strategic Outsourcing: An International Journal 9*(2), 98-125.

Kille, C., Schwemmer, M., & Reichenauer, C. (2015). *Top 100 in European Transport and Logistics Services 2015/2016*. Hamburg: DVV Media Group.

Mentzer, J.T., Myers, M.B. & Stank, T.P. (Eds.). (2007). *Handbook of Global Supply Chain Management.* Thousand Oaks, CA: Sage Publications.

Michaels, G. (2008). The effect of trade on the demand for skill: evidence from interstate highway system. *The Review of Economics and Statistics 90*(4), 683-701.

Murphy, P.R. & Knemeyer, A.M. (2015). *Contemporary Logistics (11th ed.).* Upper Saddle River, NJ: Pearson.

Paul, J. & Aserkar, R. (2013). *Export Import Management (2nd ed.)*. New Delhi: Oxford University Press.

Profir, I. (2011). Considerations on the development of intermodal transport network. *Constanta Maritime University Annals 16*(2), 61-68.

Ritchie, R. (1999). Seamless rail, road, water, air? *Railway Age 200*(12). 45.

Russo, P. (2011). Intermodal rides into the future. *Food Logistics* (131), 20-22.

Slack, B. (1990). Intermodal transportation in North America and the development of inland load centers. *Professional Geographer 42*(1), 72-83.

Simina, D., Patrick, S., & Radu, C. (2009). Economic benefits of developing intermodal transport in the European Union. *Annals of the University of Oradea: Economic Science 1*(2), 81-87.

Stinga, V. (2014). Intermodal transport – a way of achieving sustainable development. *Constanta Maritime University Annals 22*(2), *145-148.*

Tsamboulas, D. (2010). Terrorism and the Threat to Multimodal Transport – An Overview. In Bell, M., Hosseinloo, S.J., & Kanturska, U. (*Eds.*), Security and Environmental Sustainability of Multimodal Transport (pp. 3-21). doi:10.1007/978-90-481-8563-4

US Department of Transportation, Office of Intermodalism and Federal Highway Administration (1998). Toward improved intermodal freight transport in Europe and the United States: Next steps. Retrieved from https://ops.fhwa.dot.gov/freight/documents/eu_us2.pdf

World Bank (2016). *Logistics Performance Index: Global Rankings 2016.* Retrieved from https://lpi.worldbank.org/international/global

World Trade Organization (2017). *World trade statistical review 2017*. Retrieved from https://www.wto.org/english/res_e/statis_e/wts2017_e/wts2017_e.pdf

Zografos, K.G. & Regan, A.C. (2004). Current challenges for intermodal freight transport and logistics in Europe and the United States. *Journal of the Transportation Research Board 1873*, 70-78.