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SUSTAINABLE FREIGHT TRANSPORTATION: A REVIEW OF STRATEGIES

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ABSTRACT

With a growing sense of urgency for sustainability actions among consumers and most governments around the world, businesses operating in today's global supply chain are under pressure to operate in sustainable manners. Among a wide array of supply chains and logistics activities, the most visible and environmentally damaging element is extensive freight transportation. Two issues pertinent to freight transport activities that are at the center of attention in both public and private sectors are greenhouse gas emissions created by such activities and their dependence on finite petroleum resources. Freight transport-related sustainability issues notwithstanding, transportation roles in national economic welfare and competitiveness in the global market are at stake in addressing the issues. The future of freight transportation will involve a balancing act that, on the one hand, it promotes global competitiveness and economic welfare by ensuring that freight is moved efficiently and reliably within today's global supply chain context. On the other hand, it must ensure that its impacts on the environment are maintained at an appropriate level. As strategies to enhance the sustainability performance of freight transportation continue to be excogitated, the evolving nature necessitates an understanding of the developments. Based on a constant comparison analysis of relevant literature, this paper proffers a conceptualization of strategies currently employed and ideas proposed to promote joint economic-environmental sustainability of freight transportation. It is intended to render a framework for further research and dialogue among public agencies, the industry and academicians as to how the issue of sustainability in the freight transportation context should be addressed to assure long-term success.

INTRODUCTION

With a growing sense of urgency for sustainability actions among consumers and most governments around the world, businesses operating in today's supply chain are under pressure to operate in sustainable manners (Brown 2009). Among a wide array of supply chain and logistics activities, the most visible and environmentally damaging element is extensive freight transportation (Institute for Transport Studies 2010). Two issues pertinent to freight transport activities that receive particular

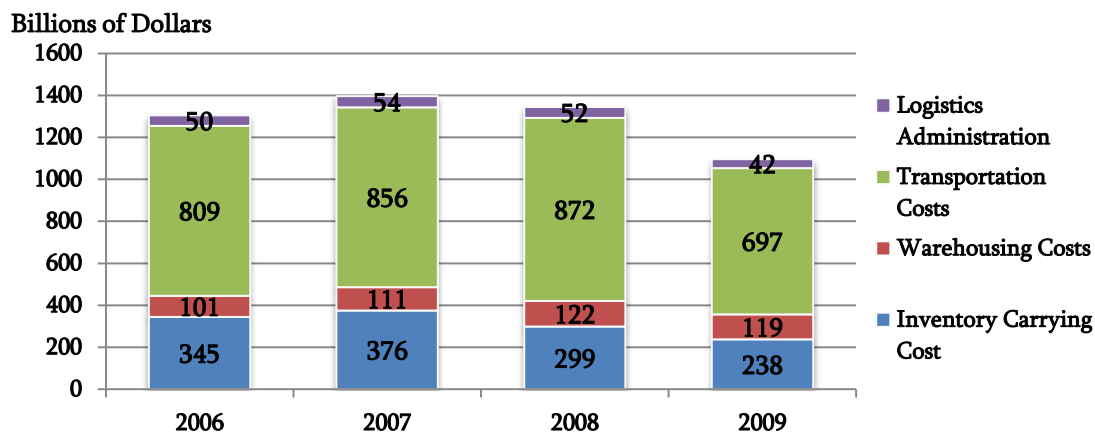
attention in both in the public and private sectors in recent years are greenhouse gas (GHG) emissions created by such activities and their dependence on finite petroleum resources.

Freight transportation is a large and fast growing contributor of GHG emissions, especially harmful CO₂ that accounts for more than 90 percent of GHGs (Varma and Clayton 2010). It is also the fastest growing contributor of GHG emissions in transportation category. Domestic freight-related GHG emissions grew by 47 percent between 1990 and 2008, nearly three times faster than those related to domestic passenger vehicles that grew by 17 percent during the same time period (Federal Highway Administration 2011a). Heavy-duty vehicles, in particular, are the fastest-growing contributor to GHG emissions within the US transport sector (National Highway Traffic Safety Administration 2010).

Moreover, goods movement in the United States and around the world is still largely driven by fossil fuel combustion, primarily diesel fuel, for most modes (Helmer and Gough 2010; McCormack and Edwards 2011; Nijkamp et al. 2000; Varma and Clayton 2010). To wit, more than 95 percent of all heavy-duty trucks in the United States are diesel-powered as is a majority of medium-duty trucks (Environment News Service 2010). The price of this finite fossil-based resource has risen significantly since mid-2000s, with world crude oil prices reaching an all time high of \$137 per barrel in July 2008 (US Energy Information Administration 2011). Along with the harmful GHG emitted by fossil fuel combustion, the heavy dependence on expensive fossil fuel resources accentuates the key environment and economic sustainability challenges confronting the freight transportation sector (McCormack and Edwards 2011; Varma and Clayton 2010).

Freight transport-related sustainability issues notwithstanding, transportation roles in the national economic welfare and competitiveness in the global market are at stake in addressing such issues. Transportation cost, as shown in Figure 1, is the largest category of US total logistics costs. Thus, transportation cost determines to a considerable extent the costs of production and distribution processes, and subsequently economic well-being and economic development of the country. Economic activities have been and will continue to depend on effective logistics to supply materials and products along the supply chain to the final consumers (Freight and Logistics Division 2008; Nijkamp et al. 2000; Varma and Clayton 2010).

Figure 1: US Total Logistics Costs 2006–09



Source: *The 18th-21th Annual State of Logistics Reports* (Burnson 2008, 2009, 2010; Wilson 2007)

Note: Inventory carrying costs include interest, taxes, obsolescence, depreciation and insurance.

Furthermore, the quality of freight transportation has become the new competitive feature and an activity of decisive importance for economic objectives in today's globalized market (Freight and Logistics Division 2008; Nijkamp et al. 2000; Varma and Clayton 2010). US economic success has so far been attributed to the efficiency and reliability of freight transportation in the United States (Lind 2009). Recognizing the gravity of freight transport as a competitive feature in the global market, trading blocs, such as the European Union, and rapidly developing countries, notably China, are devoting considerable resources to the improvement of their transportation systems. To maintain and promote its competitiveness in the global markets, the United States will need to embrace comparable focus on transportation investment (Commission for Environmental Cooperation 2011).

In essence, the future of freight transportation will involve a balancing act that, on the one hand, promotes global competitiveness and economic welfare by ensuring that freight is able to move efficiently and reliably within the contemporary supply chain context. On the other hand, it must ensure that its impacts on the environment are maintained at an appropriate level. These two aspects of sustainability, namely economic and environmental aspects, specifically GHG emissions and fossil fuel resource dependence, constitute the focus of this paper.

In the balance of this paper, the next section overviews characteristics of contemporary supply chains and how they influence freight transport activities, followed by a discussion of research objective and methodology. The state of strategies employed by the government bodies and the decision makers in the private sector to promote environmentally and economically sustainable freight transportation is then observed from literature. The final section of the paper underscores the need for a holistic approach and acknowledges challenges associated with the currently employed strategies.

CONTEMPORARY SUPPLY CHAINS AND HOW THEY INFLUENCE THE NATURE AND MAGNITUDE OF FREIGHT TRANSPORT

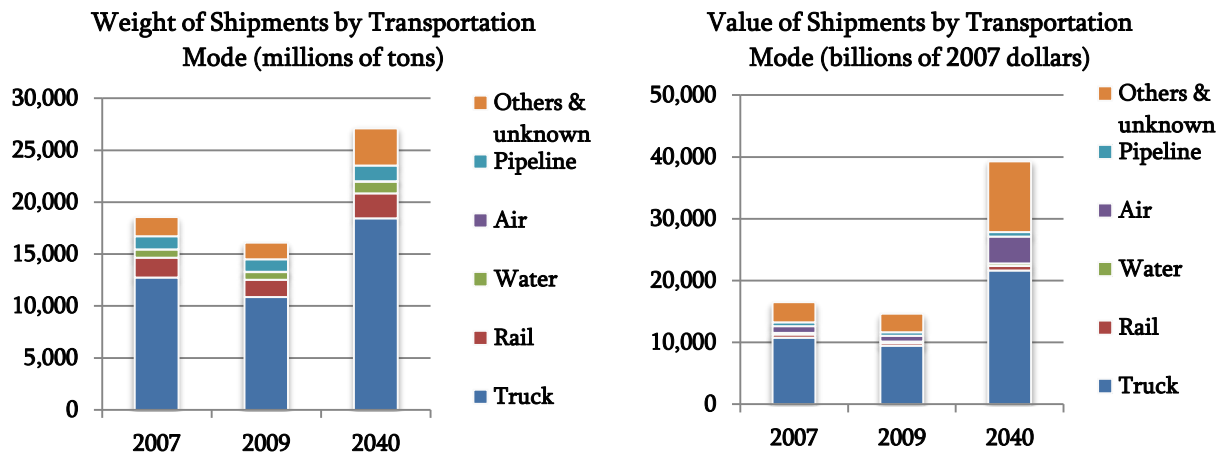
Addressing sustainability issues pertinent to freight transportation necessitates understanding of the contemporary supply chain characteristics. This is because freight transportation is primarily a commercial, market-driven activity that is driven by the needs of consumers and industry. Operated within the bounds of transport-related regulations, carriers and logistics service providers operate and make investment in a range of transport facilities and equipment in accordance with market demand and commercial criteria (Behrends, Lindholm and Woxenius 2008; Freight and Logistics Division 2008). As such, supply chain strategies play an important role in shaping modern day freight transportation.

Contemporary supply chains are essentially driven by three key features of today's market environment, including globalization, more valuable and sophisticated products with shorter product life cycles, and empowered consumers. Globalization essentially leads to longer, complex supply chains with transportation as a key linkage. The growing production specialization in the global market has encouraged the development of global supply chains that involve movements of freight many times around the world in various stages of production (Broks 2005). With the greater variety and magnitude of freight moving in the global market, modern day transportation has essentially become a key connection of local, regional, national, and international origins and destinations (Berman 2010; Nijkamp et al. 2000).

The second feature, more valuable products with shorter product life cycles lead to high inventory costs and high value of transportation lead time. Today's freight characteristics are

changing towards valuable and sophisticated products with shorter product life cycle. The Federal Highway Administration's *Freight Facts and Figures 2010* reports note that the value of freight moved is expected to increase faster than the weight, rising from \$890 per ton in 2007 to \$2,145 per ton in 2040 when controlling for inflation (Federal Highway Administration 2011a). In other words, trade in lighter-weight, higher-value products outpaces bulk commodity categories (Broks 2005). This trend is more apparent in international freight, with exports valued at \$1,825 per ton and imports at \$1,484 per ton in 2007, compared to domestic shipments valued at \$805 per ton in that same year (Federal Highway Administration 2011a). As the value of the goods rises and life cycles shorten, the importance of transport cost as a function of delivered price diminishes, whereas the value of transport lead time and costs of carrying inventories rises (Broks 2005). This is because shorter product life cycles—as manifested by the fact that products and services are duplicated quickly—present high risks of inventory obsolescence. Similarly, higher-value products mean higher costs of carrying inventories because of more capital invested in inventory. The risk factor for storing higher-value products also increases the costs of obsolescence and depreciation. And, since the physical facilities required to store higher-value products are more sophisticated, warehousing costs increase with higher-value products (Coyle et al. 2008). Faced with the foregoing challenges, supply chain strategies emphasize inventory cost reduction. Such efforts translate into greater demand on transport modes that provide faster and more reliable service to reduce not only the length but also the variability of lead time. Possessing the fast and reliable service quality, trucks carry most of the tonnage and value of total freight (domestic and international) in the United States as shown Figure 3.

Figure 3: Weight and Value of Shipments by Transportation Mode



Source: *Freight Facts and Figures 2010* (Federal Highway Administration 2011a)

A no less important feature, empowered consumers create demand uncertainties that necessitates smaller, more frequent shipments. Consumers today are more enlightened, educated and empowered than ever before by the information that they have at their disposal from the Internet and wireless mobile devices. With the opportunity to compare prices, quality, and service, consumers have become less tolerant for inferiority in any area. They demand expanded variety of products and services at competitive prices and in high quality that are made available to them conveniently, flexibly, and responsively. As a result, demand for products and services has become less predictable

(Coyle et al. 2008). To minimize financial risks in the face of uncertain demand, 'just-in-time' strategies are implemented such that freight is moved closely in line with when the freight is required. The result is that freight is moved in smaller, but more frequent shipments, and faster transportation modes are used to support reduced lead time requirement of just-in-time strategies (Aronsson and Brodin 2006; Golicic, Boerstler and Ellram 2010; Lapede 2010; Lehtonen 2006; Varma and Clayton 2010).

Together, the foregoing key features have led to time-based strategies, global sourcing, and global manufacturing mechanisms of contemporary supply chains. These mechanisms, in turn, have created the common scene in freight transportation today. Freight for the most part travels over a long distance, vehicles and containers are shipped partially full and, to meet tight delivery schedules, greater demand is placed on the fast and reliable truck mode at the expense of energy efficiency (Commission for Environmental Cooperation 2011; Denning and Kustin 2010; Federal Highway Administration 2011a; Halldorsson and Kovacs 2010; Lehtonen 2006; Varma and Clayton 2010).

RESEARCH OBJECTIVE AND METHODOLOGY

As strategies to enhance the sustainability performance of freight transportation continue to be excogitated, the evolving nature underscores required due diligence on the part of public and private sectors alike. This paper aims to gauge the big picture of strategies currently employed and ideas proposed to promote joint economic-environmental sustainability of freight transportation. It is intended to render a basis for a dialogue among public agencies, the industry and academicians as to how the issue of sustainability in the freight transportation context should be addressed to assure long-term success.

To conceptualize strategies employed to promote sustainable freight transportation, this study draws insights from extensive review of literature. Journal articles in the areas of supply chain management, logistics, transportation, environmental management, and sustainability were selected from archival material available electronically at ProQuest and Academic Search Complete. Other principal data sources are the government and organization websites such as the US Energy Information Administration, the Federal Highway Administration, and the Commission for Environmental Cooperation.

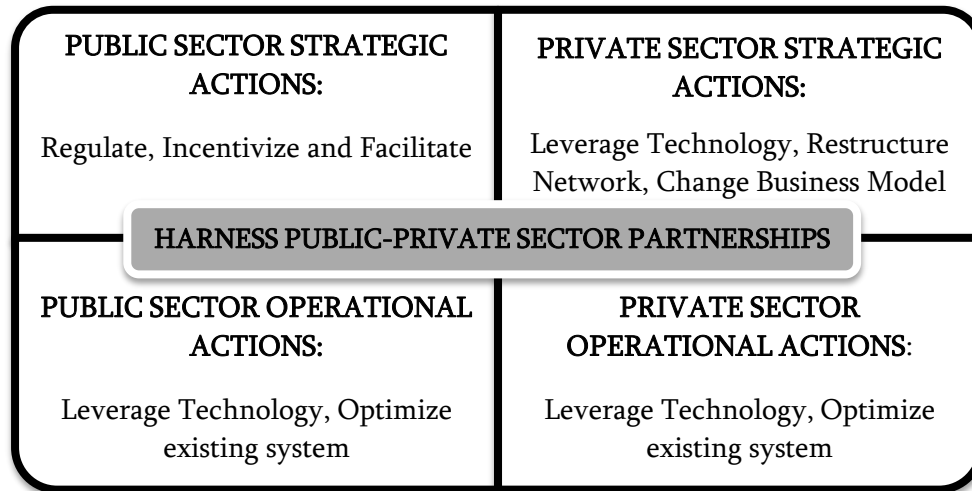
The literature content was analyzed using the constant comparison approach. Constant comparison allows researchers to analyze data and consolidate them into categories that, in turn, are continually updated and changed as additional data are reviewed (Glaser and Strauss 1967; Strauss and Corbin 1998). This method is useful in situations such as the one studied here which focus on establishing an understanding of a novel phenomenon that involves actions in organizational contexts with interaction elements in them (Bryant 2002; Goulding 2005; Mello and Flint 2009; Grawe 2009). Themes emerge from the repetitive comparison of data were then conceptualized into a conceptual framework discussed in the next section.

KEY STRATEGIES TO PROMOTE ENVIRONMENTALLY AND ECONOMICALLY SUSTAINABLE FREIGHT TRANSPORTATION

As illustrated in Figure 4, to meet the joint targets of environmental and economic sustainability, a combination of *operational* and *strategic* actions is implemented by the public and private sectors. These efforts vary from individual initiatives to differing forms of partnerships and collaborations. Strategies currently undertaken exploit multi-facet avenues, involving *technology* (leveraging

technologies), *people* (educating and training human resources), and *process* (rethinking operational and strategic approaches).

Figure 4: Conceptual Framework of Current Key Actions to Promote Environmentally and Economically Sustainable Freight Transportation



Private Sector Operational Actions

Private firms are employing a broad suite of operational strategies to reduce the environmental impacts of freight transportation. Their actions are driven primarily by a growing recognition that reducing freight-related GHG emissions can also drive improvement in efficiency and competitiveness (Anonymous 2010; Anonymous 2011; Biederman 2008; Field 2009; Hoffman 2009; Moon 2010; Stoffel 2009; Vankerckhoven 2010 Wright 2010). Commonly seen undertakings to raise the carbon productivity and fuel efficiency are adopting more fuel efficient technology, shifting to cleaner energy sources, and improving transport operation efficiency (Aronsson and Brodin 2006; Enkvist, Nauc ler and Oppenheim 2008).

Leverage Technology. Common carriers and private fleet operators are now leveraging a wide range of technologies as part of fuel-saving and carbon emission reduction strategies. They include *IT innovations* such as: sophisticated electronic devices for monitoring tractor engines, computers to measure fuel efficiency, computerized routing and scheduling software with global positioning systems (GPS), software to alert drivers to the most cost-effective fueling locations, devices that automatically switch off idling engines, and paperless solutions such as electronic bill payments. The principal benefit of using these advanced IT technologies is that by optimizing dispatching and routing capabilities, total miles traveled can be reduced. They also make it possible to measure driver performance and vehicle efficiency by remotely monitoring speed, braking, gear-shifting, idle time and out-of-route miles. Furthermore, they allow drivers to minimize the chances of getting lost, keep track of pickup and delivery schedules, and find out about adverse weather or traffic conditions. Results are reduction in unnecessary idling at loading docks and in traffic, and often reduction in the distance driven, all of which lead to fuel savings and emission reduction (Biederman 2008, 2011; Denning and Kustin 2010; Stoffel 2009; Wright 2010).

Non-IT innovations are also in use, such as: cleaner fuel, cleaner-burning engines, wide-base tires to decrease rolling resistance, more aerodynamic tractor-trailers to improve fuel efficiency (especially vehicles that travel long distances), and automatic tire-inflation systems to monitor and continually adjust the level of pressurized air in the tires for optimal rolling resistance (Biederman 2008, 2011; Denning and Kustin 2010; Solomon 2010d; Wright 2010).

It is worth noting that these wide ranges of technological innovations offer varying fuel-consumption and emissions benefits as well as different optimal driving ranges and load-hauling characteristics. They also require different infrastructure considerations and varying acquisition-cost premiums. As a consequence, different transport companies opt for different technologies that are best suited for different operational environments and delivery applications. Hybrid-electric vehicles, for instance, are ideal for the frequent stop and start of last-mile deliveries. They might work best in congested cities for pickup and delivery during the daytime so they can be recharged at night. On the other hand, liquefied natural-gas engines are appropriate for larger, long-haul tractor trailers, thus might work best in rural areas (Denning and Kustin 2010; Schulz 2010; Stoffel 2009).

Fuel Efficient Transportation Operations. To improve operation efficiencies, transportation carriers adopt *efficient routing* practices. The goals are to plan routing based on the best possible path through a series of stops and ensure that drivers spend as little time as possible at each stop (Sowinski 2007). A case in point, a UPS's multi-year initiative called '*Package Flow*' includes process enhancements such as shortening routes, minimizing idling time, combining multiple deliveries into a single stop, and loading packages in the precise order they are delivered. In all, Package Flow has saved 100 million miles from UPS delivery routes since 2003 and has reduced fuel usages by ten million gallons and carbon emissions by more than 100,000 metric tons (Stoffel 2009).

To improve operation efficiencies, carriers are also concentrating on *reducing idle time*. The US Environmental Protection Agency (EPA) studies show that an average long-haul tractor-trailer unit idles for about eight hours per day for at least 300 days per year, consuming around 0.8 gallons of fuel per hour or close to 1,900 gallons of fuel per year. It is estimated that vehicle idling costs the trucking industry about \$9 billion a year. To reduce idle time adverse effects, Wal-Mart, for example, has introduced auxiliary power units (APUs) on its private fleet. With APU installed, the main engine turns off when the truck waits idle for more than three minutes. It is estimated that the use of APU alone will lead to \$23 million in fuel savings per year (Biederman 2008; Solomon 2010d; Van Hoek and Johnson 2010).

Another area of focus by carriers is *speed reduction*. Common and private carriers nationwide are capping speeds to improve fuel efficiency. For example, Staples recently installed speed governors on its private fleet, reducing top speed to 60 miles per hour (mph). It is estimated that the speed cap increases fuel mileage by 25 percent and saves at least 500,000 gallons of fuel a year. Trucking companies are slowing down as well. Schneider National, the nation's second-largest common truckload carrier, has reduced the speed of its single-driver trucks to 60 mph. Speed reduction is estimated to save Schneider about 3.75 million gallons of fuel annually, while reducing as much as 83 million pounds of CO² emissions. Similarly, regional trucking giant Con-way has enacted reduced speeds to 62 mph, saving 3.2 million gallons of fuel a year (Biederman 2011; Schulz 2010). In the maritime industry, Maersk has reduced its top ship speed in half during the last two years, resulting in 7 percent reduction of CO² emissions and seven percent reduction on bunker fuel costs (Leach 2010a).

Transport-Driven Packaging. Packaging is among the first target areas on which shippers focus to improve transport operation efficiency. New packaging methods involve *reducing package size* to the optimal size and weight for the contents and, where possible, *eliminating unnecessary packaging layers* such as outer cartons and shrink-wrap film (Atkinson 2008; Gooley 2006; Jindel 2008). As illustrative examples, Genco and Unilever focus on reducing the amount of packaging used for each shipment. Their goals are to reduce the weight of individual products, while increasing the number of items that can be shipped on each truck or in each container (McCue 2010). Other manufacturers and retailers that implement packaging reduction initiatives are Wal-Mart, Nike, Starbucks, Aveda, HP, and Apple. To put the outcomes of these initiatives in perspective, Wal-Mart's initiative to reduce packaging has led to reduction of 3.425 tons of weight in corrugated material, 727 fewer containers from improved density and \$3.5 million in transportation costs (Jindel 2008). Similarly, HP's new LaserJet toner cartridge packages use 45 percent less packaging material by weight, reducing shipping volume by 30 percent, and increasing the number of cartridges held on a standard shipping pallet from 144 to 203 cartridges (Arkinson 2008).

Packaging is undergoing not only reduction, but also *redesign*. Examples range from advanced aseptic packaging that allows perishable products to be shipped without refrigeration, to the new square design of the gallon milk jug adopted by Wal-Mart, Sam's Club and Costco that can be stacked atop one another without using crates (Rosenbloom 2008; Smorch 2010; Tracy 2008).

Not only *shape*, but also *material* choices of packaging are changed for the purpose of transport efficiencies. Heavier materials such as glass have been replaced by other lightweight containers. Unilever, for example, introduced Ragu and Bertolli pasta sauces in flexible pouches. The pouch weighs 13.5 ounces, which are less than just the metal lid on the 26-ounce glass jar (Atkinson 2008). The lighter weight and new package shape allow more products to fit in a truck, reducing the number of trucks needed and fuel used to run them.

Collaborative Transportation. As individual players concede some gains from their individual efforts, their initiatives aimed to reduce fuel consumption and lower GHG emissions start to broaden across organizational boundary. We observe collaborative efforts among shipper, carrier and customer as part of a logistics triad (Field 2009; Lacefield 2010; Sanchez-Rodrigues, Potter and Naim 2010) that vary from *multi-shipper collaboration*, to *shipper-carrier collaboration*, and to *shipper-customer collaboration*.

Shippers are collaborating with other shippers in similar or different industries to share truck capacity or to create round trips and continuous moves. A case in point is the Empty Miles program that enables *transport pooling* in this nature. It is a subscriber-only Web-based program initiated by a nonprofit group the Voluntary Interindustry Commerce Solutions Association (VICS). So far, 42 companies have joined the program, about half of which are shippers and the rest trucking companies. As one of the participating shippers, Macy's is able to post more than 328 routes on the Empty Miles site and, so far, has found other shippers for 70 of its empty truck routes (Belson 2010). As seen from the Macy's example, this program allows participating shippers to increase the fill rate of trucks, reduce empty miles and costs, and make a direct contribution to reducing its carbon footprint (Aronsson and Brodin 2006; Cain 2010; Wright 2010).

We also see collaboration between shippers and their customers by realigning customer/store-service delivery schedules. The schedules are rearranged such that more factory-direct shipments are actualized and/or larger inventory minimums or wider delivery windows are set,

thus allowing the shipper to hold freight until a truck is full. Customers benefit from this approach as they receive fewer trucks at their docks, reducing handling and administration. This approach, combined with transportation pooling, add further a positive impact on inventory levels throughout the network of supply chains because an individual supplier does not have to wait until a minimum number of pallets is attained before shipping is executed. Instead, the supplier can add its load to the other shipper's load, thus increasing the number of deliveries from the supplier to the customer while decreasing the number of trucks. Results are fewer stocks in the retail warehouses and a higher level of customer service (Cain 2010).

Collaboration between shippers and carriers is also becoming mainstream. A transportation management benchmarking study conducted by Aberdeen Group shows various forms of shipper-carrier collaboration approaches. Examples include using more drop yard, allowing 24-hour delivery, and/or providing a mechanism for the delivery of freight that arrives early so that dock load/unload times at shippers' facilities are reduced. Shippers are also tendering freight earlier and sharing shipment plans with carriers in advance. These practices give carriers the insight and time they need to plan routes effectively and maximize equipment utilization and staffing, while limiting the amount of empty miles (Aberdeen Group 2006; Wright 2010).

Private Sector Strategic Actions

While private sector operational actions concede a certain degree of success, a paradigm shift is required to achieve long-term benefits in terms of costs and customer services along with environmental sustainability. Actions required are strategic in nature. They may involve a structural change of physical logistics systems such as locations of supply sources, manufacturing plants and warehouses. They may also encompass changes in a company's governance and control systems, employee training programs, and the development of fundamentally different relationships with business partners that can evolve into new supply chain models (Aronsson and Brodin 2006; Denning and Kustin 2010; Lee 2010).

Physical Logistics Systems Restructuring. Restructuring the physical logistics network can enhance joint economic and environmental benefits of freight transport activities. In general, by locating manufacturing sites and/or warehousing facilities close to major customer concentrations and/or supply bases, an organization increases responsiveness to customer orders, while reducing transportation distance, costs, fuel consumption and the carbon footprint. However, the principle of total system cost applies and dynamic evaluation of cost tradeoffs is required in such a restructuring endeavor. In this case, being in closer proximity to market and supply bases could indicate more warehouses in the logistics network and the resulting increased inventory and warehousing costs (Coyle et al. 2008; Schneiderman 2009).

Economic equilibrium among these tradeoffs is dynamic in nature and differs from organization to organization. It might change due to changes in fuel prices, and by extension transportation costs. As we see in recent years when fuel prices soar, the transportation costs associated with global sourcing and global production begin to weigh more heavily than before in comparison to labor costs and inventory costs. To counter the proliferating weight of transportation costs, companies restructure their supply and manufacturing networks such that they become more decentralized (Van Hoek and Johnson 2010). This economic equilibrium may change as interest rates

rise (thus, increasing costs of capital on inventory) and/or labor climate changes (thus, shifting relative costs of labor).

Personnel Training and Compensation Scheme. Training programs are an important part of lowering transport operation costs and emissions. Carriers and private fleet operators are now focusing their training programs on driving techniques that maximize fuel efficiency. Examples of such techniques are reducing speed, minimizing or eliminating hard braking and reducing air-conditioning use. Training programs also incorporate limiting idling, efficient loading specifications, routine vehicle and tire maintenance, and flexible loading and receiving schedules. To ensure changes of personal driving habits and behaviors, training programs are strategically implemented along with company policies and incentives. For example, Schneider has devised financial incentives for its drivers to ensure that drivers adhere to its mandated speed limits of 60 mph for single-driver trucks (Biederman 2011; Denning and Kustin 2010; Schulz 2010; Young 2008).

Incentives and Performance Measure Alignment. To make major structural changes and induce collaboration, all parties involved in freight transportation must align their incentives in such a way that suppliers, customers, carriers and 3PLs are rewarded for their sustainability performance. In fact, this strategic action is key to the sustainability of the sustainability initiatives. They may involve changing contract specifications, modifying performance measures, altering payment schemes, and/or using other types of incentives such as providing direct aid in the form of training or subsidies (Lee 2010).

Sustainability criteria are now part of traditional cost and quality criteria when *selecting and negotiating with supply chain partners and transport service providers* (Enkvist, Naulé, and Oppenheim 2008; Halldorsson and Kovacs 2010). Leading companies are beginning to make purchasing decisions based on the need for a sustainable environment and even exercise mandates on their transport service providers and suppliers. A case in point is Stonyfield Farm, an organic yogurt maker located in Londonderry, New Hampshire. Stonyfield is incorporating environmental considerations into performance scorecards and encouraging its carriers to participate in the EPA's SmartWay Program. It also inserts stipulations that motor carriers use new, lower-emission equipment into any new transportation contracts it signed (Anonymous 2010; Cooke 2009b). Another example is Pepsico. In February 2009, the company mandated its roughly 210 carriers that they be certified by the EPA's SmartWay Transport Partnership. Pepsico also works with each carrier to score and track mileage efficiency and CO² emissions per mile (Biederman 2010). This practice is not limited to shippers, but is implemented by transport service providers as well. Given that many freight transport companies subcontract their vehicles or work with a variety of vendors to deliver goods, *contract specifications* that encourage or require these external parties to employ the green practices are now in place. For instance, since subcontracting is a major part of DHL's operations profile, DHL has begun negotiations with its subcontractors to improve efficiencies and reduce emissions, wherever feasible (Denning and Kustin 2010).

In the same vein, meaningful *performance metrics* are essential to sustain the sustainable transportation strategies (Davies 2008). This is particularly the case given that the current widely-used logistics performance metrics in terms of *costs* (e.g. transport costs, inventory carrying costs, material handling costs), *quality* (e.g. on-time and damage-free delivery, complete order), and *time* (e.g. order cycle time length and variability, response time) do not adequately address sustainability

aspects of freight transportation. Companies begin to develop detailed metrics that monitor the emission and cost impacts of their sustainability enhancing initiatives. A 2010 AMR Research surveyed 158 logistics and supply chain executives and found that the most common sustainable transportation measures are: fuel reduction (46%); route optimization and delivery efficiency (44%); continuous moves and/or freight co-mingling (37%); use of alternative fuels (34%); and empty miles reduction (32%) (Biederman 2010). Specific examples are Dell Inc. that measures its GHG emission reductions, Office Depot Inc. and FedEx that track fuel usage and its associated GHG impact, and Stonyfield Farm that measures the amount of CO² generated per delivered ton of product (Cooke 2009b; Golicic, Boerstler and Ellram 2010).

Another area of strategic actions is *customer service programs*. To enhance sustainability practices, customer service programs offer customers a discount for full container and truckload orders. In contrast, an additional fee is imposed on customers for expedited and emergency deliveries that require the use of less-fuel-efficient transport modes, and for shipments that require shipping significantly less than a full container or full truckload (Lapide 2010). As a specific example, Stonyfield Farm promotes truckload delivery by establishing order minimums for customers and beginning to require 48 hours' advance notice of order revisions. Along with route optimization, the company was able to eliminate more than four million miles and about 2,500 truck trips from 2006 to 2007, reducing its CO² per ton delivered by about 40 percent (Anonymous 2010; Cooke 2009b).

Public Sector Operational Actions

Public sector operational approaches to improve transport systems with regard to sustainable development center on managing transport infrastructure networks in a different way such that capacity of traffic within existing transport systems improves (Nijkamp et al. 2000). Notable examples of such operational actions are restrictions on truck delivery hours in cities and applications of intelligent transportation systems.

Restriction on Truck Delivery Hours in Cities. Several cities in the United States and European Union (EU) have implemented time of day restrictions on truck deliveries in their downtown core areas. Specific examples include: (1) **Boston, MA**, where vehicles with commercial plates are prohibited from using certain downtown streets within the Downtown Crossing area except between 6:00 PM and 11:00 AM; (2) **Cambridge, MA**, where a truck ordinance was enacted in March 2003, restricting deliveries between 11:00 PM and 6:00 AM except for specified truck routes (Seattle Urban Mobility Plan 2008); and (3) **Barcelona, Spain**, where programs were initiated to move deliveries to nighttime or fringe hours, especially from 11–12:00 PM and 5–6:00 AM. These programs aim to divert trucks to other less congested time periods, and help to reduce emissions by reducing idle time on traffic (Anonymous 2008).

Application of Intelligent Transportation Systems. We observe the development of intelligent transportation systems aimed to improve the efficiency of existing transportation systems that yield multiple benefits, including congestion relief and emission reduction. For example, signal control systems with enhanced CO² sensor capabilities are now made available by Siemens AG. The solution was deployed in Europe and Asia as an Urban/Freeway Traffic Management System, and in the United States as both freeway and regional management applications (Siemens Energy & Automation 2009). With a CO² sensor incorporated into the traffic control technology, the systems control traffic

signals to improve traffic flow when GHG emissions rise (Helmer and Gough 2010). Electronic sign boards to reroute traffic around the congested areas can also be used to reroute traffic around the congested areas (McCormack and Edwards 2011). Another example is the Federal Aviation Administration's Next Generation (NextGen) Air Traffic Control system. Its goal is to address the impact of air traffic growth by increasing National Airspace System capacity and efficiency, while simultaneously improving safety, increasing user access and reducing environmental impacts. To achieve its NextGen goals, FAA is implementing new Performance-Based Navigation routes and procedures that leverage emerging technologies and aircraft navigation capabilities. Required Navigation Performance (RNP), a satellite-based navigation system, is one of the key enabling capabilities of NextGen. It provides more efficient flight paths from origin to destination with consequent reductions in fuel consumption and GHG emissions (Federal Aviation Administration 2010; Sowinski 2010).

Public Sector Strategic Actions

Public sector strategic actions employ a host of policy instruments, ranging from direct regulation, incentives, to facilitation.

Regulate: Emission and Engine Standards. All new vehicles sold in the United States must be certified that they meet emissions standards set by the EPA. California is the only state empowered with the authority, the California Air Resources Board (CARB), to develop its own emission regulations. Its standards have been traditionally more stringent than the EPA requirements, albeit their structure is similar. Other states have a choice to either implement the federal emission standards, or adopt California requirements (United States Emission Standards Diesel Net 2010).

Along with the national and state emission and engine standards, *local port authorities* are executing their own mandates. Driven by concern about air quality and emissions caused by aging and/or poorly maintained trucks used in port drayage operations, some ten ports in North America have established or are developing clean-trucks programs. Most of these programs call for retrofitting existing trucks with diesel particulate traps and gradually phasing in 2007 model or newer trucks by 2020 (Cutler 2010; Mongelluzzo 2011). A case in point is that of the Port Authority of New York & New Jersey. The port authority announced its plan to ban pre-1994 model year trucks from serving its marine terminals after January 1, 2011. The port has made available \$28 million in financial assistance—one-quarter of which will come from federal grants—to help operators replace up to 636 trucks with pre-1994 model engines (Solomon 2010c).

Trucking are not the only mode subject to emission limits and engine standards. In March 2008, EPA adopted *emissions limits for locomotive and marine engines*. The regulation follows three strategies: (1) it sets more stringent emissions standards for remanufactured locomotive and marine engines; (2) it creates standards, phased-in starting in 2009, for newly rebuilt locomotive and marine engines; and (3) it sets standards for new marine and locomotives diesel engines beginning in 2014 and 2015, respectively. The new engine standards are based on advanced engine technology that requires ULSD fuel, which will be available nationwide by 2012 for off-road engines (Denning and Kustin 2010; Sowinski 2007).

It is worth noting that the key difference of emission standard policies in the railroad and trucking industry and the *maritime industry* lies in the scope of institutional presence. Since ocean shipping is a global industry, it falls under common international standards managed through the

International Maritime Organization (IMO), the United Nations' specialized agency responsible for improving maritime safety and preventing pollution from ships. To develop a mandatory regime to control GHG emissions from ocean vessels, IMO's Marine Environment Protection Committee in 2008 approved amendments to Marpol Annex VI to phase in the use of low-sulfur distillate fuel on vessels. Sulfur content will be reduced from 4.5 percent now to 0.5 percent in 2020. US Congress in 2008 passed legislation approving the Annex VI regulations, so the mandate will apply to vessels calling at all US ports (Barnard 2010; Biederman 2010; Broks 2005; Mongelluzzo 2011; Young 2008).

Regulate: Renewable Fuel Standard. In the United States, the EPA developed a renewable fuel standard and adopted it as a final rule in 2007. The set standard is aimed to reduce both petroleum fuel use and greenhouse gas emissions. In the trucking industry, the law requires that truckers increase their consumption of biodiesel to at least 1.15 billion gallons in total for the years 2009 and 2010 combined. The amount will rise to one billion gallons annually by 2012. In 2009, only 350 million gallons of biodiesel were consumed, according to data from the American Trucking Association (ATA) which represents several large private fleets and for-hire carriers (Solomon 2010d). Similar requirements in EU were voted by the European Parliament's energy committee in September 2008. It requires that at least 10 percent of road transport fuel used in the EU come from renewable sources such as biofuels by 2020. At least 4 percent should come from biofuels that do not compete with food crops or from other renewable sources such as green electricity (Young 2008).

Incentivize: Taxation and Pricing. There is a widely held view that transportation user prices that incorporate the costs of environmental and other externalities have a key role to play in sustainable freight transportation. Market-based mechanisms in the forms of taxation and pricing, particularly *carbon pricing* are viewed by sustainable advocates as potentially the most effective policy tool to accomplish GHG emissions reduction (Anonymous 2011; Commission for Environmental Cooperation 2011; Institute for Transport Studies 2010; Moon 2010).

In the United States, there is the legislative push in the current Congress to adopt a "*cap and trade*" system—much like the one many European nations have already put in place to comply with the Kyoto Protocol. Under cap and trade, a company or industry is given a permit to give off a quota of carbon dioxide. If it stays below its quota, a company can sell its unused allowances to a company that is exceeding its quota, thus creating an incentive to reduce carbon emissions. The expectation is that carbon pricing will generate investments in technologies or activities that have lower carbon emissions than business-as-usual (Anonymous 2011; Commission for Environmental Cooperation 2011; Cooke 2009a; Institute for Transport Studies 2010; Moon 2010).

Incentivize: Grants and Subsidies. Several federal, state and local programs provide assistance to speed up old engine turnover, clean the air and protect public health. Examples of these programs include the National Clean Diesel Emissions Reduction Program (DERA), California's Carl Moyer Program and Boston's Clean Air Vehicles Program.

Federal Program: Diesel Emissions Reduction Act (DERA). First signed into law in 2005 under the Energy and Policy Act, the bill establishes voluntary national and state grant and loan programs for emission reduction projects. These projects include: installing emission control devices or idle-reduction technologies, upgrading or repowering engines, using cleaner fuels, replacing equipment, or creating and implementing innovative financing programs to support diesel emissions reduction

projects. It is estimated that when all of the older diesels have been replaced by new models that meet current EPA standards, at least 110,000 tons of particulate matter (more commonly known as soot) and 2.6 million tons of nitrous oxide emissions will be eliminated. That is the equivalent of taking 13 million of today's trucks off the roads (Denning and Kustin 2010; Solomon 2010a);

State Program: The Carl Moyer Memorial Air Quality Standards Attainment Program (Carl Moyer Program). California's Carl Moyer Program was created in 1998 when the state budget allocated \$25 million to fund a lower-emission heavy-duty engine incentive program. Legislation enacted shortly thereafter established the statutory framework for the program. The program's focus is to achieve reductions of criteria and toxic pollutants, with the goals of helping the state meet its Clean Air Act commitments and improve public health. The program also reduces greenhouse gases by funding hybrid and electric vehicles and equipment. The program is currently funded at a level of about \$140 million a year through 2015. Demand for Carl Moyer funds annually exceeds their availability (Denning and Kustin 2010).

Local Program: Boston's Clean Air Vehicles Program. The City of Boston offers grants to pay for half the cost of any verified diesel retrofit device, while the vehicle owner pays the other half. The vehicle must be a pre-2007 on- or off-road diesel vehicle. The grant amount is up to \$10,000 per business, with the option of retrofitting multiple vehicles. Eligible applicants are Boston-based businesses or others with a significant presence in Boston. The program began in 2008 and was extended for an additional year, as funding was still available. Yet, the lack of in-use regulations, with the exception of equipment used on government projects, means there is little incentive for businesses to voluntarily clean up their vehicles (Denning and Kustin 2010).

Facilitate: Research and Development Support. The potential of technological change to contribute to the development of a sustainable freight transportation system is considered to be significant. Large investments are usually needed for research and development to bring about technologically induced changes. In this respect, the direction of government research funding can influence and facilitate the direction of technological development. Institutions such as the granting of property rights of new inventions (patents) are another instrumental to further technological development (Aronsson and Brodin 2006; Rietveld and Stough 2004).

Facilitate: Infrastructure Development to Promote Modal Shifts. Strategic infrastructure development involves a varying degree of re-design and radical changes of the infrastructure system to promote modal shift and behavioral changes in managing freight transportation (Nijkamp et al. 2000). One such example is the federally funded infrastructure program known as **TIGER (Transportation Investment Generating Economy Recovery)** aimed to divert cargo and passenger traffic from congested roads to underutilized inland waterways, many of them along coastal highways. Eighteen rivers and coastal routes have been invited to participate in the program. A notable project under this program is a **marine highway** project, nicknamed the **Green Trade Corridor**, in northern California. The project is being seeded with a \$30 million grant from TIGER and is designed to take cargo off the roads and rails, and instead move them by barge between the ports of Oakland, Stockton, and West Sacramento. Under the project, set for completion in early 2012, barges will move cargo along the inland waterway system from Stockton and West Sacramento to the Port of Oakland for ultimate shipment to Asian destinations. As such, the project will not only reduce carbon emissions from trucks

traveling the busy Interstate 580 corridor, but will also create new alternatives throughout Northern California to transport exports to the Far East (Solomon 2010b).

A similar infrastructure development approach to push for modal shifts is *EU's Marco Polo program*. This program aims at improving the environmental performance of European freight transportation by freeing the roads of an annual volume of 20 billion tonne-kilometers of freight, the equivalent of more than 700,000 trucks a year travelling between Paris and Berlin. As in the United States, it is built on the recognition that Europe's roads are overused and congested. The first Marco Polo program ran from 2003 to 2006. Marco Polo II runs from 2007 to 2013. Marco Polo provides grant as financial support in the crucial start-up phase of a modal-shift or traffic avoidance projects as well as projects providing supporting services to enable freight to switch from road to other modes efficiently and profitably. The EU has also initiated a "*Motorways of the Sea*" concept that aims at introducing new intermodal maritime-based logistics chains in Europe, making fuller use of maritime transportation resources, as well as rail and inland waterways, as part of an integrated transportation chain. However, the concept is still in its early stages and has not yet successful in creating a paradigm shift in modal choice (Commission for Environmental Cooperation 2011; European Commission 2010; Leach 2010b).

Harness Public-Private Sector Partnerships

The EPA SmartWay Transport Partnership Program is considered the leading example of a successful *market-based initiative* and *public-private partnership program* that supports the greening of freight transportation. It is a collaborative initiative between government and the freight sector to improve energy efficiency and reduce GHG emissions. Its members include trucking companies, railroads, ocean carriers, logistics providers and shippers such as Best Buy, Target, Coca-Cola, Johnson & Johnson, Procter & Gamble, and Wal-Mart. Similar programs of this kind in North America are FleetSmart (Canada) and Transporte Limpio (Mexico) (Biederman 2008; Commission for Environmental Cooperation 2011; Lacefield 2010; Varma and Clayton 2010).

SmartWay initially targeted carriers when it was launched in 2004. In order to become a certified partner in the program, a carrier must agree to reduce emissions by a certain percentage each year. SmartWay was then extended to shippers, allowing it to push the environmental and economic benefits it offers upstream into supply chains. Carriers gain a competitive advantage as preferred providers for participating shippers while shippers gain a better understanding of their supply chain carbon footprint and can better work to optimize performance. Since its inception in 2004, SmartWay has enabled its members to collectively saved 1.5 billion gallons of fuel (\$3.6 billion dollars in fuel costs saved), and achieved 14.7 million metric tons of CO² reductions—the equivalent of taking 2.88 million cars off the road. Its success is further evident by the fact that the program has doubled in size each year since 2004 (Biederman 2008; Lacefield 2010; Varma and Clayton 2010).

CONCLUDING REMARKS

In this paper, we observe strategies implemented by the public and private sectors to achieve the joint targets of environmental and economic sustainability. The strategies currently undertaken have a certain variety of operational and strategic actions, and individual and collaborative efforts.

Current Strategies

Operational strategies center on reducing the environmental impact of freight transportation within the existing assets and infrastructure. Technological solutions are favorable and can be observed in both private and public sectors. Governments and authorities now employ new technologies to manage transport infrastructure networks so as to improve traffic flows within existing transport systems. This approach not only helps to reduce GHG emitted and energy consumed by idle and congested traffic, but also increases the capacity of the existing infrastructure. In a similar fashion, private firms leverage cleaner energy and fuel-efficient technologies, along with information technologies to improve the efficiency of their operations and reduce transport impacts on the environment.

At the strategic level, actions are taken with aspiration towards a longer-term and wider-scale transition to a sustainable freight transport economy. They involve a structural change that is not limited to physical infrastructure, but also entail freight transport practices, and governance and control systems. Government bodies are exercising various instruments, ranging from incentives to mandates in order to encourage the use of alternative fuels and adoption of fuel-efficient vehicles and equipments. Infrastructure development, taxation and pricing, and sustainability policy development are all parts of government strategic actions. The direction of research funding is also used to influence and facilitate the development of clean technologies. In the private sector, physical network restructuring and changes in business model and performance measures are auspicious approaches.

Challenges

While the current strategies yield certain a degree of success, a number of challenges should be acknowledged in moving forward. First, while improvements in vehicle technologies could play a significant role in reducing GHG emissions and fuel consumption, their impacts are dependent on the rate at which these new technologies penetrate the current vehicle fleet. To date, several companies are using advanced vehicles on an experimental basis. Many of these projects have yet to be deployed on a fleet-wide level and the implementation timeframe is estimated to be long-term, most likely two decades or more (Turchetta 2010). To put this challenge in perspective, consider that of the millions of trucks on the US road today, most of the engines are still pre-2007 (the first model year for trucks with new emission control technologies that make use of the EPA-mandated, ultra-low-sulfur diesel). Only about 200,000 new truck engines are sold every year, and the US EPA notes that it will likely take until 2030 for all the trucks on the road to have “green” engines. Turnover of inefficient rail technology also takes considerable time. The typical service life for American locomotives and freight cars is about 40 years (Commission for Environmental Cooperation 2011).

By the same token, the impact of emissions reductions from renewable, low-carbon fuel mandates depends on a number of factors, including price and availability of infrastructure and vehicle technology. Prices of clean fuel e.g. biodiesel, low-sulfur fuel remain relatively high. Biodiesel prices have been steadily rising in recent years and are currently more than \$1 a gallon higher than comparable diesel prices (Solomon 2010d). Similarly, the cost of low-sulfur fuel for vessels is about twice that of today’s bunker fuel (Mongelluzzo 2011). Furthermore, vehicle technology upgrades can be expensive, for many clean fuels require some degree of engine modification, while others such as electricity require completely different power vehicles (Turchetta 2010).

Moreover, given the active infrastructure development to promote modal shifts in the United States and the EU, particularly marine highways, their viability is essential for long-term success. Marine highway is inherently a slower means of freight transportation than the current dominant over-the-road trucks, especially on short to intermediate hauls. There is also the additional cargo handling needed that not only drives up costs, but also increases transit times. Furthermore, the Jones Act, an 89-year-old law requiring that vessels used in domestic trades be U.S.-built, -registered, and -crewed, is viewed to render marine highway services uncompetitive (Solomon 2010b). These concerns are supported by a recent study by the Texas Transportation Institute. The study identifies many obstacles to the US Marine Highways program, including: service/marketing issues, operating cost issues, infrastructure and equipment issues, government/regulatory issues, operational constraints, and vessel-related issues (Commission for Environmental Cooperation 2011).

Moving Forward

In moving forward, a holistic approach involving a continuum of decisions and practices that encompass all aspects of transportation in both public and private sectors is imperative (Cooke 2009a; Helmer and Gough 2010). Reducing the environmental impact of freight transportation in the face of increasing trade and economic growth in the United States requires much more than continued progress on fuel economy and transport technology (Anonymous 2011). For a start, the major driving force in fuel and vehicle innovation is the profit-seeking goal of entrepreneurs in response to a potential market demand. Therefore, institutions are needed to drive technological change towards sustainable outcomes by ensuring that demand and markets for the new technologies are created and sustained (Aronsson and Brodin 2006; Rietveld and Stough 2004).

In the same vein, strategies must be devised with an understanding of and appreciation for two important fundamentals of the contemporary transport dynamic. First, freight transport phenomenon is primarily a repercussion of tradeoffs made between prices, transit time, and reliability of transport services, and other supply chain costs such as inventory carrying costs, manufacturing costs, and costs of lost sales (Broks 2005; Lamngård 2009). Second, freight transportation is a market-driven commercial activity that is driven by the needs of consumers and the freight industry. As such, the accountability for sustainable freight transport exists throughout the supply chain—from the business customers and the originator of the goods who may put demands on how the goods are transported, to any third-party logistics providers who manage transportation carriers on the shippers' behalf (Freight and Logistics Division 2008).

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