■ JAYANTH JAYARAM, Feature Editor, University of South Carolina

In the following article, Professor Mike Gorman of the University of Dayton points out the importance of considering transportation infrastructure for effective global supply chain management. Using a variety of examples, Gorman identifies several challenges facing managers today in coordinating shipments that span multiple regions using multiple modes of transportation. The article ends with suggestions for solving the problems pertaining to the transportation infrastrusture such as congestion, security issues long lead times, and excessive working capital requirements from longer pipeline and safety inventories.

Transportation and the World Economy

by Michael F. Gorman, School of Business, University of Dayton

Outsourcing and international ization are the most dramatic developments in today's manufacturing environment. Major enablers of this trend are many. First, we witness declining tariffs and protectionist policies world-wide due to agreements such as NAFTA, and formation of groups such as the World Trade Organization, and the European Union. As a result, investment and growth in more stabilized emerging nations such as China has been growing. Second, low cost email and telephony technology for communication and satellite-based tracking of product world-wide enables international coordination and reduces risk of product loss. Finally, a primary enabler of internationalization is the more affordable and reliable international transportation brought on by the evolution of the world transportation infrastructure: roads, rails, ports, and oceanic shipping lanes.

In this essay, we look at how transportation infrastructure decisions have major implications for manufacturers, transportation providers, and government policy makers and how the world's transportation infrastructure and logistics industry continue to evolve to support these new international logistics patterns.

Internationalization of production requires increased focus on transportation and logistics costs and risks. In much of the supply chain planning literature, transportation is an important but overlooked "forgotten link." Most discussions of supply chain surround suppliers, manufacturers and distributors, while paying little attention to the mode of transit between these supply chain participants.

Although international freight transportation efficiency and economy has improved dramatically in the last decade, many importers are still learning to deal with its complexities. The guidance of third-party logistics companies with international expertise is in demand as neophyte international manufacturers and retailers learn to navigate the turbulent waters of international shipping. International freight shipment typically requires many parties: Shipment consolidators, both foreign and domestic truck and rail carriers, oceanic ship lines, freight forwarders, and third party logistics providers all must be coordinated—to say nothing of the shipper and receiver! This complexity requires special attention in the overlooked "transportation supply chain."

International Transportation Impacts on Logistics and Production Planning

With the outsourcing and internationalization of production, there is a dramatic impact on calculus surrounding

Michael F. Gorman
is an associate professor at the University of Dayton in the Department of MIS, OM and DSC. He has 10 years of experience in the rail industry at BNSF Railway and regularly consults for both shippers and carriers in transportation and logistics issues. His work has been published in Manufacturing and Services Operations Management, Annals of OR, Interfaces, Applied Economics, *and* Transportation Quarterly, *among others. He was a finalist in INFORMS' Daniel Wagner Competition for Applied Research in 2005. He is a referee for numerous peer-reviewed journals. Mike has five years of service (including chair) in INFORMS Rail Applications special interest group. He is currently the treasurer of the Cincinnati-Dayton local chapter of INFORMS.*
Michael.gorman@udayton.edu

transportation, inventory, and logistics on production planning and global sourcing decisions. Clearly, a primary driver to internationalization is the desire for lower costs of production. Lower costs of production directly decrease the investment per unit in work in process and finished goods inventory. Meanwhile, these inventories are traveling over dramatically longer distances, dramatically increasing the total transportation cost per unit of finished product. As a result, transportation costs compose a larger percentage of the total product cost of internationally produced goods than their domestic counterparts. This pattern is apparent when observing the steady growth in freight transportation expenditures as a percentage of total manufacturing costs throughout the 1990s. With higher fuel prices spiking up transportation costs, this pattern promises to continue into the future. Savvy manufacturers are heavily weighing these higher transportation costs as they design their international supply chains and develop their strategic production and logistics plans.

Of course, lead times are much longer with internationalization. Transit time through the Pacific is up to two weeks, and this time does not include the time in transit both from the production location to the port, nor the time from the domestic port to the final consumer. Growth in South East Asian regions or countries has been predominantly in port cities to avoid costly transit over an underdeveloped transportation infrastructure, but the production growth is spreading inland. In the U.S., average truckload haulage distances have been steadily on the climb, from 370 miles per haul in 1988 to over 450 miles per haul in 2000 (a 26 percent increase) as a larger percentage of freight moves from port cities over longer distances to their final destination (Eno Transportation Foundation, Transportation in America, 1999, p. 51). More time in transit amounts to more "pipeline" inventories between source and demand points. Further, given longer lead times in international transportation, there is typically more variability in demand during lead time giving rise to larger safety stocks.

International shipping is a large-lot phenomenon. To achieve improved economies of scale to overcome the huge distances traveled, ever-growing gargantuan container ships now carrying up to 8,000 containers apiece cycle through the Pacific at regular intervals bringing imports to the U.S. But even domestic freight transportation experiences dramatic economies of scale. Generally, the cost to move a ton of freight one mile for air freight is over two times the cost of "less than truckload" (LTL) per ton mile, which is itself over three times the cost of full truckload per ton mile. While intermodal rail (trailer or container on a rail flatcar) usually offers a twenty-five percent discount to truck, it is still often twice as much per ton mile than box car. The dramatic discounts for larger lots, coupled with the dramatically longer international and domestic distances traveled by freight with internationalization gives strong incentives for larger lot sizes. These larger lots directly impact production, inventory, warehousing and distribution networks for importers.

As described earlier, the numerous handoffs inherent in international transportation create numerous endogenous points of failure due to the sheer number of participants in an international freight shipment. These endogenous risks are dwarfed, however, by the exogenous risks facing international supply chains. The sources of delay in international supply chain include regularly experienced, minor delays due to oceanic weather patterns (storm and winds) and on land (snow). Since 9/11, delays in customs clearance have been a regular nuisance, though with new processes and technologies these delays are abating. Finally international supply chains are more subject to significant, catastrophic events such as severe weather (tsunamis, hurricanes and floods), international supplier bankruptcies, and geopolitical instability as in the Middle East. Overall, considering all these potentially disruptive forces, it would seem these "irregular occurrences" aren't so irregular at all. The result of all these uncertainties gives rise to yet another form of safety stock—one to account for added uncertainties in when the product might arrive.

International Transportation Impacts on Inventory

These trends run opposite of Just-in-Time (JIT) ideals such as suppliers locating close to customers, reducing inventories by shipping in frequent small lots, and reducing lead times and variability. JIT inventory practices under international sourcing strategies are largely impossible; the economies of scale from large lot shipments far outweigh savings from any inventory reductions. Yet companies often try to maintain inventory reduction programs while they outsource internationally. As a result, firms that claim JIT practices while sourcing from the Far East (e.g., Walmart) are merely "pushing inventory around the supply chain" through Vendor Managed Inventory (VMI) and consignment programs without any real reductions in inventory across the supply chain.

For example, in the U.S, the holiday retail import rush begins in the transportation industry on the west coast in August and completes in early December. In fact, business models have arisen to help reduce the financing costs through third-party financing of this inventory, reducing the cost of inventories through lower interest rates rather than actually lowering inventory levels.

With longer pipelines full of larger lot sizes, earlier reorder points to account for higher demand during lead time and uncertainties in shipment times, how can manufacturers afford it? In simplest terms, the cost of inventory is Cost/Unit * Holding costs * quantity of inventory. Let's see what's happening to each of these components of inventory costs. First, we must note that the driving force behind internationalization is reducing the cost of production, so while the quantities of inventory in transit is undoubtedly increasing

with internationalization, the cost per unit has dramatically fallen, thereby reducing the inventory holding cost per unit per unit of time. Second, while interest rates have risen of late, they are still at historic lows, generally making inventory more affordable. Finally, technology solutions such as RFID, satellite tracking, and Internet-based communications standards such as XML may help mitigate some of the upward pressure on inventory levels and reduce some of the non-interest costs of inventory such as shrinkage and administrative costs. It would be interesting to quantify the net impact of these confluences on total inventory holding costs in the international supply chain.

Transportation Infrastructure Impacts on the Supply Chain

Infrastructure capacity has some known "pinch" points which regularly create significant delays for manufacturers. For example, Chinese rail deficiencies hinder transport of freight to its outbound ports. Container ships have been heavily reallocated from the Atlantic to the Pacific Ocean, reducing Atlantic shipping capacity. Western U.S. ports, especially L.A. harbor, are often backed up as a result of larger and more frequent container ship deliveries. U.S. rail networks are often congested and facing rail car shortages. Trucking companies regularly face longhaul driver shortages. In a sense, the boom in internationalization was enabled by the improved transportation infrastructure, but the growth in freight far outstrips the rate at which the infrastructure can be continually improved and expanded.

As a result of the susceptibility to international infrastructure deficiencies and supply chain risks, manufacturers are faced with developing modified supply chain strategies which include duplication and contingency plans in their supply chains. For example, importers may employ a port diversification strategy in which primary ports are augmented with backup or secondary ports to allow for product diversions and exposure to port congestion. Alternatively, a mixed domestic and international sourcing strategy allows for avoiding the congested ports altogether when necessary. Both of these strategies create a loss of economies of scale in operations and transportation, and force second best routing and sourcing.

More creative load consolidation and deconsolidation strategies, coupled with distribution centers located closer to the ports, allow for higher velocity product movement in smaller lots while retaining the economies of scale necessary for long distances. However, this strategy requires additional product handling. Further, transloads and merge-in-transit facilities closer to the port may require the additional overhead of multiple distribution centers.

Of course, importers are forced to regularly resort to airfreight shipments to adjust for supply chain shocks on the fly when they are caught running too thin in the supply chain given its uncertainties. This high-cost remedy, along with the supply chain "insurance strategies" described above, diminish the returns to internationalization and outsourcing. The redundancy inefficiencies that result from these strategies are necessary in order to achieve a robust supply chain.

Implications for the International Transportation Infrastructure

As we described above, the world-wide transportation infrastructure accommodates international trade. Infrastructure investment lags and mismatch with demand create pinch points which can be costly for manufacturers and retailers. While China's production and exports are booming, geographically, the growth has been primarily in coastal areas. For China to continue to grow inland, the production boom will have to move inland, and in order for that product to reach the ports, the infrastructure must be massively improved.

Each capacity shortfall must be addressed in a coordinated fashion. Ports must figure out how to deal with larger container ships effectively and with reduced port congestion. Further, the handoff costs between ocean vessel and domestic transportation modes must be reduced. Finally, the right mix of road and rail capacity must be developed to support import freight traffic patterns.

In the U.S., the vast majority of transportation infrastructure investment is undertaken by the federal government, and the vast majority of that is in the U.S. road network. On the other hand, the rail network is privately owned. These two planning entities face entirely different considerations for their investment decisions. Domestic freight infrastructure coordination between these modes is difficult, leading to suboptimal transportation infrastructure.

When highway congestion reaches unacceptable levels, because voters are caught in the same congestion as freight, public demand is created for greater road capacity. Because historically freight growth rates are used to predict future needs, the highways expand. Over $100 billion is spent on roads each year in the U.S. on a network that is the single largest asset owned by the public sector and is steadily growing (see U.S. Department of Transportation (DOT), Bureau of Transportation Statistics (BTS): Table 1-A).

On the other hand, although U.S. railroads are as healthy as they have ever been since the Stagger's Act deregulated them in 1980, they are still financially challenged to create sufficient infrastructure to accommodate rail traffic without significant congestion delays. Approximately $15 billion is spent each year on the U.S. freight rail network by major railroads (see American Association of Railroads, Freight Railroad Capacity Issues), but despite these investments, the network is actually shrinking in terms of total rail miles operated (see BTS Table 1-1: System mileage within the US).

The Department of Transportation predicts that freight transport in the U.S. will increase 55 percent between 2000 and 2020 (see DOT BTS: Freight Analysis Framework). Understanding how

that freight will move is critical to building the infrastructure to support it. Transportation infrastructure planners need to consider changes in production, inventory, and distribution patterns to create an infrastructure which better matches the freight needs of international shippers.

Given earlier observations of the lower product cost, oceanic large lots, long lead time and uncertainty, and longer domestic haul of international freight shipments, total logistics cost modeling would indicate a shift towards lower cost transportation modes in the domestic U.S., if even at the expense of higher inventories. The drive for faster and more reliable domestic transportation deliveries is dampened by the reality that this component represents a smaller component of the inventory pipeline and inventories have already traveled around the world in slower, less reliable modes. Moving fast in the "last (2000) miles" can't make up for that. The fact that a growing portion of freight is already moving in relatively slow and erratic oceanic vessels suggests that some freight may shift modes from smaller, faster shipments domestically to larger lot shipments with lower cost. Some readers may be surprised that rail still moves over 42 percent of the U.S. freight gross ton miles (see US DOT, BTS: Table 1-41), and is growing roughly as fast as truck, despite the rail network shrinkage.

However, a private market solution for building freight infrastructure may not be achievable. A significant benefit to rail freight transportation accrues to the general public in the form of reduced road congestion and pollution relative to truck freight (an estimated one-third of the benefit is a "public" good). A potential solution to investment misallocation is in public-private partnerships that split the cost of the investment according to how the benefits are accrued.

An example of this type of partnership occurred in the Alameda Corridor project in Los Angeles. Public and private funds financed a rail connection between the Los Angeles harbor, and western railroads reduce the local truck drayage, thereby both reducing road congestion and pollution in Los Angeles, and reducing the cost, complexity, and time for these shipments. Neither public nor private concerns could justify this project on their own, but together the public and private benefits far outweighed the investment costs. In a similar way, the European Union is striving to promote its network of inland waterways that may help alleviate road and rail congestion on that continent.

Conclusion

Transportation and logistics are critical components of any company's supply chain, and with growing internationalization, this importance is magnified. As a result, transportation infrastructure is critically important to world economy. Effective and sufficient investment enables continued internationalization and continues to lower total cost of living through lowering total landed costs. As internationalization and freight shipments grow, infrastructure must keep pace to avoid pinch points which reduce effectiveness. In order to plan infrastructure effectively, carriers and public entities must develop an understanding of freight shippers' logistics decisions, and in some cases develop a better partnerships to provide adequate infrastructure.

Web Resources

Freight Bottom Line Report: http://freight.transportation.org/doc/FreightRailReport.pdf

US Dept. of Transportation Highway Cost Allocation Study: http://www.fhwa.dot.gov/policy/hcas/summary/sum1.html

US Dept of Commerce and Bureau of Transportation Statistics Commodity Flow Survey: http://www.census.gov/econ/www/se0700.html ■

USDA's Economic Research Service Announces Competitive Awards Program

USDA's Economic Research Service (ERS) Program of Research on the Economics of Invasive Species Management (PREISM) is pleased announce a competitive awards program for Fiscal 2006. ERS initiated PREISM in 2003 to address economic issues and decision making related to managing invasive species in increasing global agricultural markets. Included are exotic crop pests and foreign livestock, poultry, zoonotic diseases, but also exotic pests or foreign diseases affecting public lands, ecosystems, or urban systems that are addressed by USDA programs. Research under this program concerns economic aspects of space, dynamics, risk, uncertainty, irreversible effects, or institutional frameworks that pertain to invasive species, and has a strong focus on practical applications to government prevention, surveillance (detection and monitoring), and management (control, containment, eradication, and restoration) decisions.

In 2006, ERS is seeking proposals that focus on applied economic research and/or decision support system development that has direct implications for USDA programs, policies, and decision making concerning invasive species. Priority Research Areas include: 1) Institutions and Incentives for Efficient Invasive Species Prevention and Management, 2) Practical Decision Analysis for Invasive Species Management, and 3) International Dimensions of Invasive Species Management.

Anticipated funding for 2006 competitive awards is approximately $1,000,000. Proposals are due April 28, 2006.

Those interested in submitting proposals can find the 2006 request for proposals and other information at:

http://www.ers.usda.gov/Briefing/InvasiveSpecies/preism.htm

To directly view the 2006 competitive awards program RFP, click on:

http://www.ers.usda.gov/Briefing/InvasiveSpecies/invasivespecies0206awards.pdf

For more information about PREISM, contact Craig Osteen (costeen@ers.usda.gov) or William Hahn (whahn@ers.usda.gov).