

Defining the Range of Urban Congestion Impacts on Freight and their Consequences for Business Activity

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Abstract

The causes and impacts of urban traffic congestion are intrinsically tied to changes occurring in business practices and the economy. The freight delivery requirements of businesses and their sensitivity to congestion are also increasing as many types of business seek to serve wider markets and apply new logistics and production technologies with increasing reliance on just-in-time supply chains, overnight courier services, intermodal facilities and international gateways.

In response, regional business organizations are starting to take a leadership role in focusing attention on urban traffic congestion and its impacts on freight movement and business activity. This paper uses examples from three areas where business organizations have been working with public agencies to study the economic implications of congestion growth and the economic benefits of investing in efforts to mitigate it. It utilizes findings from those studies to develop a taxonomy of the ways in which urban traffic congestion is changing the freight delivery and operational decisions of businesses, and increasing their costs. It then identifies needs for improved transportation and economic analysis methods that are sensitive to those factors.

1. INTRODUCTION

There is a growing body of evidence in the field of economic development showing how rising traffic congestion can have significant impacts on regional economies. Equally important, there are multiple paths by which traffic congestion leads to impacts on economic growth, which may span impacts on market access, freight delivery, supply chains, international trade and intermodal connections. The result is a need for transportation planners to recognize and measure the different facets of congestion, so that they can be fully covered in analysis models and appropriately considered in decision-making. This paper summarizes findings from three studies showing the business impact and economic consequences of congestion, which were sponsored by regional business organizations in Vancouver, BC; Chicago, IL and Portland, OR. It provides a framework for defining the multi-modal impacts of traffic congestion on business, and it then discusses needed improvements in analysis methods to capture their broader economic consequences.

2. PAST RESEARCH: THE NATURE OF TRAFFIC CONGESTION IMPACTS ON BUSINESS AND THE ECONOMY

Most of the existing research literature on economic costs of urban traffic congestion is at a very broad-brush level, demonstrating that congestion can affect business productivity through changes in travel time costs and the size of market areas that can be served from any given business location. However, there is little information beyond that level to explain the ways in which congestion affects different types of freight movement, different types of businesses, or the ways in which businesses can respond to those conditions.

A 2003 study of the National Cooperative Highway Research Program laid out a framework for defining congestion and viewing the ways in which it can affect the economic feasibility, competitiveness and growth of economies [1]. Congestion was defined as "*a condition of traffic delay (i.e., when traffic flow is slowed below reasonable speeds) because the number of vehicles trying to use a road exceeds the design capacity of the traffic network to handle it.*" That study examined how congestion affects producers of economic goods and services through three general avenues of impact: (1) availability of skilled labor, (2) cost of acquiring specialized material inputs, and (3) size of customer delivery markets. It also showed that the severity of these impacts varied systematically by industry, with greater impacts hitting industries that had greater requirements for skilled workers and higher levels of truck shipping. It also showed that traffic congestion can nullify some of the agglomeration benefits (economies of scale) associated with operating a business in larger urban markets.

This work followed on the footsteps of 1996-1998 works addressing the relationship of productivity to density and accessibility (Ciccone and Hall [2], Weisbrod and Treyz [3]), and a 1999 study by Prud'homme and Lee [4] which demonstrated how urban traffic congestion can reduce the effective size of an urban area's markets. Recent work by Graham [5] also showed how urban road traffic congestion, by constraining the benefits of agglomeration, can serve to reduce achievable levels of productivity in congested urban areas. However, all of these studies

operated at a general level when discussing productivity and accessibility, and none of them investigated the “micro-level” mechanisms by which businesses actually see their productivity eroded by traffic congestion. Furthermore, they have seldom distinguished congestion effects on freight movement from other effects on commuting travel. However, such information is necessary if transportation models are to appropriately capture the full nature of congestion and its economic effects, and if examination is to made of policies that may be taken to minimize those effects.

The one major area where business impacts have previously been examined at a more specific level is the literature on travel time variability, which grows with increasing traffic congestion. While much of this literature focuses on passenger cars, there is also a growing base of research on freight logistics and time-sensitive delivery which does indicate that there is a substantial premium placed on travel time reliability and the avoidance of delay for this class of travel. (See Rao and Grenoble [6], Small et al. [7], Cohen and Southworth [8], Grant-Muller and Laird [9].) Yet again, questions remain about the extent to which business decisions regarding their location, scheduling, and deployment of vehicles and labor resources can both contribute to congestion and be changed to offset or minimize the effects of rising traffic congestion. These issues and their economic consequences can only be addressed through more detailed micro-level analysis of business processes and business decision-making. This article seeks to examine and clarify those issues.

3. PERSPECTIVE FOR VIEWING URBAN CONGESTION AND FREIGHT ISSUES

Roles of Business Organizations. An impetus for more detailed studies of the business impacts of urban traffic congestion has come from urban business organizations that have become concerned about the future viability of critical industries and freight transportation functions in the face of growing traffic congestion. For instance:

- The “Vancouver (BC) Gateway Council” is an organization of “senior executives from industry and government who subscribe to a common vision that Greater Vancouver become the Gateway of Choice for North America.” It focuses on preserving and enhancing the gateway roles of the region’s international seaport and airport, and their supporting highway and rail facilities. Concerned that rising traffic congestion would choke those facilities, the Gateway Council initiated a study of the regional economic consequences of urban congestion (and benefits of investment to minimize congestion growth) through a cooperation agreement with local, regional, provincial and federal government agencies. Findings were released in the study: *Economic Impact Analysis of Investment in a Major Commercial Transportation System for the Greater Vancouver Region* [10]
- “Chicago Metropolis 2020” (CM2020) is a membership organization of “business, labor, civic, religious and governmental organizations” dedicated to “ensure the preeminence of the Chicago Metropolitan Region in the 21st century.” A focus area is transportation and its connections to land use and the economy, and the need to maintain the competitive position of Chicago as the nation’s foremost rail and truck freight hub. CM2020 initiated a study of problems facing freight movement in the region and steps necessary to address them. That

included analysis of the regional economic consequences of urban congestion and benefits of investment in a program to minimize congestion growth. Findings were released in the study: *The Metropolis Freight Plan: Delivering the Goods*, which included a technical study “Assessing the Economic Impacts of Congestion Reduction Alternatives” [11].

- The Portland Business Alliance (PBA) is the Chamber of Commerce of the greater Portland (OR) metropolitan region. One of its key concerns is to enhance the region’s economy by supporting policies that maintains trade competitiveness and mobility for people and freight. This is particularly important because distribution and warehousing is also seen as one of the region’s key business clusters. To address the rising congestion problem, the Alliance partnered with Metro (the regional council of governments), the Port of Portland and the Oregon Department of Transportation to assess the relationship between transportation investments, congestion and the region’s economic future. Findings were released in the study: *The Cost of Congestion to the Portland Region* [12].

Key Issues. These studies are notable for three basic reasons.

- (1) They all focused on business and economic impacts. While they included passenger cars and peak period commuting, they all placed particular emphasis on the need to better understand and appreciate the economic role of freight movement and its sensitivity to rising traffic congestion.
- (2) All three studies focused on needs for examining and addressing the specific needs of freight access along freight corridors and routes to/from inter-modal rail yards, airports and/or seaports.
- (3) The involvement of business organizations and business leaders in all three studies enabled a greater degree of information on the specific nature of business impacts and business responses to congestion. That led these studies to focus greater attention to identifying ways in which particular classes of inter-modal facilities and corridors, particular times of day and particular industries are most affected.

In each of these cities, the business organization served to bring in the perspective of key business leaders. The Vancouver and Chicago studies included meetings with business organization representatives, while the Portland study included more extensive in-person and telephone interviews with individual business executives. These experiences have made it possible to better identify and classify the key ways in which traffic congestion affects businesses, their locations, operating procedures and freight shipping patterns.

4. CATEGORIZING THE FACETS AND MECHANISMS OF BUSINESS IMPACT

Using a wide range of business interviews, meetings and studies of key facilities and corridors, the three studies pointed to a series of ways in which the growth of traffic congestion affects various sectors of the economy. A key finding from all three studies is that the facets of congestion impacts go far beyond just the travel time and travel cost factors associated with

delay. They also include fundamental impacts on the size of business markets, the scheduling of business processes, the deployment of personnel and vehicles, the dispersion of business locations and use of intermodal connections. All of these issues bear directly on either the competitive cost of doing business in a region or the ability to expand business operations to meet the demands of a growing region.

Processes. We can systematically describe the processes by which congestion leads to economic impacts in terms of seven major mechanisms:

- (A) Effects on Freight and Service Delivery
- (B) Effects on Business Scheduling
- (C) Effects on Business Operations
- (D) Effects on Intermodal Connections
- (E) Effects on Worker Travel
- (F) Effects on Business Locations
- (G) Effects on Other Activities (Externalities)

The next section takes each of these seven processes and discusses how congestion leads to effects on them.

Measures of Impact. The economic implications that result from the above processes occur in terms of either (A) added costs of business activity or (B) constraints on business activity growth. The element of business activities that are affected may be in: (1) transportation sectors that are directly affected, (2) manufacturing and wholesaling sectors that are indirectly affected through their dependence on transportation for workers and materials, or (3) retail and service industries that also depend on worker, customer and product deliveries. These categories are shown in Table 1 below. The next section identifies how each of the seven processes lead to cost and constraint impacts imposed on those three broad economic sectors. It discusses the nature of these business impacts, drawing on general findings from the three studies, with specific examples drawn from the detailed Portland area interviews.

Table 1. Classification of Economic Cost and Economic Growth Constraint Impacts Caused by Congestion Growth

	(1) Transportation, Delivery	(2) Manufacturing and Wholesale	(3) Retail and Services
(A) Cost Impacts			
Labor Cost			
Operating Cost			
Capital Cost			
(B) Growth Constraint Impacts			
Time Schedule			
Location			
Scale Economies			

(A) Effects on Freight and Service Delivery

Problem: Delivery Markets. With rising congestion, the time it takes to get from the warehouse to the first stop/delivery (stem time) has increased in most metropolitan areas. In addition, cross-region movements to subsequent delivery stops become more difficult than they have been in the past. In effect, congestion shrinks the delivery area that any one driver and vehicle can serve. This means that there need to be more vehicles on the road (to maintain and grow distribution and trucking markets) and routes need to be changed more often. Beyond adding direct driver and vehicle costs, these changes bring added a need for continuing adjustments in scheduling drivers and deliveries. The major economic impacts are classified as follows:

- **Labor and Operating Costs: Delivery.** Congestion directly affects the cost of deploying crews for delivery of products and services. These effects can include labor and fuel costs due to longer truck operating hours, fewer deliveries or completed jobs per crew trip, and/or greater reliance on additional truck and van trips when current driver hours of service limits are reached.
- **Operating Costs: Inventory.** Reliable delivery schedules allow for efficient “just-in-time” processing, but delays effectively undo those opportunities for business efficiency. As a result, interviewed businesses with chronic delivery problems (in the Portland region) reported that they have had to increase inventories by as much as 5% to 8% compared to 5 years ago. Some of that is due to road congestion and some to railroad delays.
- **Capital Costs: Vehicles.** A growing number of delivery firms have developed methods for “on-the-fly” rerouting or regular adjustment of departure times, loading and preparation of loads for delivery. However some firms, particularly those with large, heavy loads moving between established manufacturing operations, do not have the flexibility to make these adjustments. Slower turn-around between plants requires adding more vehicles to sustain production, or alternatively, adding shifts or cutbacks in production schedules.
- **Constraint on Location and Scale Economies.** In addition to increasing the cost of product and service delivery within a core region, congestion effectively shrinks the boundaries of the area that can be served from any one warehouse or manufacturing plant. This also affects the size and dispersion of these facilities, as discussed later under (C) business operations and (F) business location issues.

(B) Effects on Business Scheduling

Problem: Delivery Times. The growth of PM peak congestion has reduced, and in many cases even eliminated, late afternoon stock/merchandise deliveries in larger urban areas. It has pushed starting times into the early morning hours for businesses involved in transportation and distribution. A growing number of businesses, irrespective of sector, now face restricted operations after 3PM. Many transportation and warehousing operations have adjusted scheduling so that most vehicles return to the warehouses or distribution centers by the early afternoon. Most consignees have been able to accommodate these early shipping deadlines into

their operations. However, if afternoon congestion trends continue, with the shortening of the window for final outbound shipments, manufacturing and transportation operations will be hard-pressed to maintain current levels of productivity and current final outbound shipment schedules. The major economic impacts are classified as follows:

- **Labor Cost: Increased Morning Deliveries.** The shift towards early morning (4-6AM) deliveries in the retail sector means that stores are now required to have staff loading and stocking in the morning (2-3AM) or during swing shifts. This creates problems for many businesses in that they must bring staff in early in the mornings to receive deliveries. Most retailers and produce consignees are reluctant to allow “drop shipments”, especially of perishables or high-value retail merchandize. If deliveries are made too early or too late in the day, extra in-store shifts are required.
- **Constraint on Scale Economies: Shipments.** Truck dispatch times are limited by the ability to prepare and load trailers from the time they arrive in the afternoon to the time that they are scheduled to depart in the early morning. The ability of warehouse operations to assemble loads and stage them for loading in the evening shifts, reposition trailers based on available dock/door capacity, and stage trailers for departure is constrained by available time between drop off and whenever trailers with backhaul materials are ready. Increasing the number of trailers on-site is limited by available space and adds costs for redundant equipment.
- **Operating Cost: Backhaul Operations.** Backhaul efficiencies are important to many transportation and logistics operations as the ability to support efficient backhauls reduces the number of vehicles, number of operators and time required for normal operations by these firms. Backhaul opportunities and efficiencies are more significantly affected by afternoon congestion than outbound shipments. Firms that have developed sophisticated routing and logistics management practices integrating backhaul management into their processes have more recently noted increased overtime and the need for “rescue drivers” to conform to the legal limitations on “hours of operation”.

Backhauls can also be important for other businesses that have their own vehicle fleets. In Portland, OR for example, Providence Health Systems generates significant amounts of recycled materials (surgical and non-surgical), plastics and paper. Collection and recycling of these wastes and potentially toxic materials has depended on backhaul for efficient recovery of recyclables. Congestion during backhaul operations is becoming a growing problem because it limits loading times for the evening delivery cycle. As a result, smaller vehicles in greater numbers are being used to service evening deliveries to the 29 clinics and hospitals served by the firm.

- **Cost of Labor: Relief Drivers.** In the case of transportation and warehousing industries, first shift start times for drivers have been moved to very early in the day (often 4 to 6 AM in the Portland case). This is because afternoon congestion has become a problem for firms with scheduled deliveries or routes, and most firms want to avoid overtime pay or violating state/federal regulations on truck driving hours (typically 11 hours per day). Some firms have begun to rely on “rescue drivers” to avoid those situations. In addition, evening swing shifts

have been instituted in many warehousing and distribution businesses so that returning trailers can be loaded for the next morning deliveries.

- **Constraint on Time Schedule: Closing “Window of Opportunity” for Activity Shifts.** Businesses that can adjust to the long-term effects of evening congestion by shifting operations to the early morning hours have done so in many cases (imposing the burdens of adjustments to very early shifts to their employees). However, as morning travel demand continues to grow in what were traditionally considered shoulder time periods, available highway capacity shrinks to increasingly affect the operations of most of the businesses that have become dependent on efficiencies of operating in this time period. As there is no other feasible time period in which to operate, the effects of a saturated morning peak accompanied by shoulder times that are also operating at capacity are resulting in much more serious impacts on business operations than the effective elimination of the evening peak hours.

(C) Effects on Business Operations

Problem: Inventory Management. Throughout the 1990s, reductions in inventories increased efficiencies in the manufacturing and transportation sectors. Many economists believe that increased inventory management and increasing efficiencies in logistics and supply chain management in that decade contributed significantly to the modulation of the business cycle and helped to lengthen economic expansion and moderate business cycle corrections, which were often driven by the need to “work off” excess production and accumulated inventory. These efficiencies are beginning to erode due to roadway congestion.

Retailers and distributors are also faced with a rapidly growing inventory management issues for other reasons. In addition to having to move more of a particular item due to increase sales volumes (often on contracting margins), they are also stocking a larger number and greater diversity of items in order to remain competitive with large, “big-box” operators. Increases in volume and mix of products mean space constraints have become critical factors in their ability to serve customers and retail outlets. Inventory management and distribution efficiency are the most important factors in achieving the levels of productivity needed to remain competitive. Limited space inside existing warehouses and lack of expansion space encourage just-in-time inventory systems, which are highly dependent on reliable deliveries. Congestion delays mean that the ability to manage the flow and inventory required in rapid turn-over businesses can be significantly diminished. The major economic impacts are classified as follows:

- **Operating Cost: Retail Stocking.** Retail operations depend on high volume sales, especially because margins for competitive retailing operations are constantly being reduced. The primary factors driving higher throughput are the need to offer a greater range of products and providing continuous availability of retail stocks in the face of uncertain delivery/delay. Timing of deliveries is critical because it is related to stocking time – the ability to get products on shelves, or from loading docks to in-store storage. Stocking and transfers involving in-store storage often involve shift workers who are at either the beginning or end of their shifts. Delays in receiving deliveries due to highway congestion result in overtime payments for deliveries for distribution warehouses operated by the chain, or in missed or refused deliveries in the case of vendors or third party delivery. This has

contributed to a need for affected businesses to be keeping more inventory on-hand – both in distribution warehouses and in manufacturing operations. In these ways, congestion imposes costs that are often unmeasured and unrecognized in traditional modeling or by current cost analysis.

- **Operating Cost: Inventory Management.** Most of the efficiencies in supply chain management over the past decade have been attributable to advances in inventory control and management of materials, components, and finished goods in the supply chain. Squeezing as much efficiency as possible through high levels of automation in warehousing and load management has produced significant efficiencies in warehousing and distribution industries. However, the effects of congestion are eroding the significant progress that has been made in inventory management and warehouse control. Two types of changes appear to be happening simultaneously. First, reductions in labor costs attributable to in-warehouse efficiencies are being absorbed by the costs of the over-the-road operations (more equipment and drivers to deal with congestion and driver hours of service limitations). Second, by re-introducing uncertainty in shipping and receiving attributable to the over-the-road and “last mile” portion of the supply chain system business are forced into looser scheduling , setting lower delivery targets, and adding additional inventory (a reversal of recent trends in lowering inventory) to allow for uncertainty in delivery times.
- **Constraint on Time Schedules: Impaired Cross-Docking Operations.** Efficiency and feasibility of cross-dock operations are tied to the ability of originators to deliver inbound loads within window of time needed to reposition loads for outbound customers – typically very early in the morning. Late inbound delivery creates storage and loading problems. As the communications and inventory control infrastructure required to support cross-docking operations becomes more widespread and more critical to improving efficiency and lowering costs of transportation and logistics, delivery reliability will become an even greater issue in the successful adoption of cross-docking in warehouse and logistics management. Insofar as this practice becomes more integrated into transportation and warehousing operations, consideration will be given to locating new facilities in places where congestion is less of a factor in creating uncertainty about delivery times.

(D) Effects on Freight Facilities and Intermodal Facilities

Problem: Freight Flow Bottlenecks. Traffic congestion can be highly localized or pervasive, affecting an area as small as turning movements at a single location, or as broad as an entire corridor or region. The causes can include: (a) intersection flow controls or lane designs, (b) railroad grade crossing designs and schedules of use, or (c) peak traffic demand levels exceeding capacity along major roadway routes. Any of these problems can lead to freight flow bottlenecks. However, it is the freight flowing to intermodal terminals that tend to be most vulnerable to congestion delays, because there are typically operating schedules involved in intermodal transfers (most often between trucks and either trains, aircraft or ships) and a missed transfer can have substantial impacts for just-in-time manufacturing or delivery processes that are far greater than the cost of driver time and vehicle operating cost. The major economic impacts are classified as follows:

- **Labor and Operating Cost: Rail Facilities.** Rail yards and rail-dependent industrial parks typically depend on having good truck access into and out of those facilities. Increasing congestion in core urban areas is a growing concern, as it leads to increasing operating costs and reduced productivity. This can occur in two ways. First, missed trans-loading schedules cost both the time of the trucking and unloading crews and require trucking firms to reschedule their operations. These costs are not immediately recoverable and must be internalized in most businesses as charge-back to missed rail deliveries is not possible. Second, use of broadened pickup and delivery schedules to avoid missed deliveries also carries a cost of vehicle and driver time. In some areas, the potential for cross-docking of rail-borne deliveries has been abandoned as a feasible efficiency option.
- **Constraint on Location: Rail Facilities.** A longer term response being observed in large urban areas such as Chicago is a movement of rail-dependent manufacturing industries to outlying areas, which in turn is also leading railroads to open new intermodal facilities in those same outlying areas. A consequence of this trend is that manufacturing and distribution services are becoming more dispersed, and drays to and from the intermodal facilities are becoming longer. The end result is that more truck-miles are needed to support freight intermodal freight movement.
- **Labor and Operating Cost: Air Cargo.** Access to air cargo in most major metropolitan areas is most important for businesses involved with high value and/or time sensitive cargoes. The issue of air freight schedules and capacity is also complicated by access time – especially for those businesses located some distance away from regional airports. Many businesses also rely on inbound shipments from global sources for materials and components involved in manufacturing. Increasingly, though, time-sensitive imports and exports are being trucked long distances between origin/destination locations and the large international gateway airports. The primary reason for choosing longer and a more costly ground component of the air freight movement is avoidance of congestion (both on major highways and at the airports themselves) occurring at the times that products are ready to ship. While that solution allows businesses to minimize schedule uncertainty, it also comes at a cost of reduced productivity.
- **Constraint on Time Schedule: Air Cargo.** The reliance on air-truck transfers makes roadway congestion a particularly critical issue affecting scheduling for international air shipments, such as “high tech” manufacturing that relies on US-Asia production processes. For these shipments, congestion on routes to airports can also affect production schedules. For instance, Intel’s computer chip manufacturing plant in Oregon has reportedly moved their last daily shipment departure time from 5:30pm to 3:30pm for outbound shipments through Portland International Airport in response to increased congestion. That is because a missed flight can mean loss of inventory and production at the receiving location and the potential imposition of significant cost penalties if production of chip cutting and testing operations is affected.

Congestion on routes to airports also affects industries such as business and financial services that depend on overnight courier services. For instance, the pickup at overnight courier drop

boxes in downtown Vancouver has been moved up to 4 PM (or earlier), partly in response to growing delay along the congested truck route between downtown and the airport.

- **Labor and Operating Cost: Delivery to Marine Ports.** Major seaports serve as important international gateways for import and export goods moving from overseas locations to a broad hinterland. As a result, rail cars and trucks come in from a broad area to converge on the port facility and its access route(s). This presents a congestion challenge for many major seaports (as identified in both the Portland and Vancouver studies). The problem is exacerbated by the potential severity of impact associated with missed schedules. A truck that is delayed and misses closing time at the port's truck gate must wait till the next day. Depending on the day, it is possible that the container may miss its scheduled ship and have to several days or longer to get picked up on another ship heading for that same port. If a driver cannot ensure arrival time early enough to prevent that possibility, then it may be necessary to arrive earlier in the morning or one day earlier. Either way, there can be additional driver and vehicle scheduling, time reservation and operating costs incurred because of the congestion delay uncertainty.

Some ports are now trying to reduce the severity of this delay by extending their hours of operation at truck gates. Some are also instituting truck reservation systems at their container facilities, to even out the truck arrival times (which can also help reduce congestion delay and uncertainty).

(E) Effects on Worker Travel

Problem: Commuting Time and Expense. Most employers require employees to bear the costs of longer travel times to, from and through congested areas. There is also growing evidence that employers also offset some of these higher commuting costs by offering higher wage rates in areas where transportation costs are higher. An even more problematic situation is the change towards earlier start times for shift workers, which has moved from transportation to warehousing and distribution industries and also to affect retailing. The major economic impacts are classified as follows:

- **Labor Cost: Extra Shifts and Work Hours.** The movement towards earlier start times for warehousing and distribution workers is occurring in many congested metropolitan areas to facilitate continued freight operations that rely on over-the-road movements. In some areas, shifts are now being staggered to allow for more efficient operations and these staggered shifts begin as early as 2:00AM for distribution and warehousing operations attempting to serve areas of similar size compared to ten years ago. This constitutes a major change in working conditions. In addition, it often precludes or reduces the ability of workers to use public transit or ridesharing options, which can effectively constitute yet another element of cost increase for workers.
- **Cost of Operations: Worker Schedule Reliability.** As congestion in larger and rapidly growing metropolitan areas increases, many businesses have noticed an increase in congestion-related delays for scheduled start-times. While such incidental (although increasing) arrival delays can generally be accommodated in service and professional

occupations and work environments, it can pose a more serious problems for production, manufacturing and transportation industries. The costs of start-time delays and arrival reliability are difficult to quantify and have not traditionally posed a noticeable problem for businesses. However, the increasing frequency of start-time delays and the cumulative burdens of congestion on business operations is beginning to focus management attention on all aspects of congestion costs on business operations – even those that have been historically overlooked or deemed less significant in the past.

- **Labor Cost: Work Travel.** Increased congestion has affected personnel movement during business hours. This was reported across a number of larger businesses including utility companies, the insurance industry and major regional-serving businesses such as hospitals and medical facilities. Travel, especially between offices, for meetings and project-related team conferences is being increasingly adversely affected by congestion. This has resulted in more the on-the-clock travel time for senior managers as well as project and departmental staff and therefore less productive time spent managing and addressing operational issues. (Note: while conference calling and virtual meetings are being pressed into service more frequently, each of these options has distinct disadvantages that have become evident with their use over time. Transition from historical multi-site operations for larger, more concentrated operations centers imposes significant costs for businesses, and compounds the commuting time/expense burdens borne by workers in these industries.)

(F) Effects on Business Location Issues

Problem: Business investment decisions concerning the site location of new business facilities and the expansion of existing facilities are made on the basis of the relative productivity and efficiency that can be obtained from alternative locations. For warehousing and distribution facilities, these decisions are typically made by considering the labor market area that can be tapped from a given location, and the customer or delivery market that can be served from that location. For manufacturers and distributors with multiple operations, the location decision is a complex matter that also considers inter-location movements and the extent of overlap or gaps in coverage of markets among shipments between locations. Transportation has historically played a major role in these decisions. The major economic impacts that result are classified as follows:

- **Constraint on Scale Economies.** A major constraint on providing delivery services from an urban location to a surrounding region is the fact that congestion limits the outbound (morning) and especially the afternoon return times. More generally, slower speeds and increased travel times that result from rising congestion have the effect of shrinking the distribution radius from which a business may reliably make deliveries and serve existing customers. It also makes expansion into new regional markets more difficult. This also cuts into the cost-effectiveness of manufacturing and distribution operations by precluding the opportunity to gain “economies of scale” associated with expanding production and operations activities.
- **Labor and Operations Cost.** Rising congestion during afternoon periods also affects costs of operations. Traffic congestion at the time of afternoon vehicle returns, which often include backhauls, can create an overtime/over-hours situation for the drivers involved. The

results is increasing costs and reducing productivity for both the vehicles and the drivers. This further cuts into the cost-effectiveness of distribution operations because efficient backhaul management is one aspect of logistics management that traditionally provides competitive advantages to dedicated trucking and logistics firms.

- **Constraint on Locations.** As a consequence of the preceding congestion effects, many new warehousing, distribution and transshipment facilities are being located far from the metropolitan areas traditionally “home” to such operations. In the New York area, warehousing serving the ports of New York and New Jersey are currently operating in central New Jersey. In several regions, major manufacturers and food distribution businesses have located new distribution and warehousing operations further away (from 500 to over 1000 miles) from the core metro markets in order to remain competitive in serving multiple markets.

(G) Effects on Interaction with Other Activities (Externalities)

Problem: Land Use and Modal Choice Impacts. Economists define “externalities” as effects by one set of parties on others who did not have a choice and whose interests were not taken into account. For instance, earlier parts of this paper indicated that urban traffic congestion impacts can lead to more sprawled land use patterns and fewer modal choices for workers. These are both impacts that are clearly beyond the direct impacts on travelers and freight users that are most often considered in transportation planning and investment decisions. These impacts are further explained below:

- **Capital Cost: Localized Effects of Land Use and New Development** - Warehousing usually try to locate in “edge” areas of urban regions. Firms that located in these relatively low-density, open spaces as few as eight to ten years ago are often now finding that they are facing higher levels of congestion on segments of the highways system they depend upon for serving their customers. Interviews revealed that often the cause is (ironically) the process of increasing infill development and “densification” of development in formerly low-density areas where the firm had originally located. Expansion, especially of warehouse and distribution facilities, is often limited both by new and proposed non-commercial land uses and by significantly higher land costs. The option of using existing facilities with greater intensity is often limited or precluded by factors such as the growing length of truck trailers and the associated need for more staging space. The end result, then, is a trend towards warehousing and distribution firms moving even further out to yet lower density areas.

For manufacturing businesses with regular, high-volume movements between intermediate and final production sites, congestion has also significantly increased the time needed to move intermediate products, partial assemblies and raw materials. In some areas, especially where older manufacturing sites have been rehabbed into mixed use development, the associated gentrification and conversion of older and unused warehousing space has combined with traffic congestion to further compound delays in routine shipment patterns. The result is additional pressure for manufacturing plants to move out of urban areas.

- **Constraint on Time Schedules and Modal Choice for Workers.** Of the various adjustments made by businesses when attempting to address congestion throughout the course of their working day, the most obvious way that businesses “externalize” their costs is by asking their employees to maintain traditional working hours thereby imposing the costs of congestion (earlier departure times, longer travel times for commuting, and associated higher costs of non-travel time transportation such as vehicle operating costs). As previously discussed, alternatives to auto-based commutes during off-peak travel times are often unavailable, or poorly supported by alternative modes when work shifts are adjusted to meet business requirements. While providing adequate alternative transportation is clearly not a traditional role of private businesses, a series of congestion effects (including expansion of congestion periods, operational decisions required to address business costs of congestion, and location decisions) are shifting the cost and time burden of maintaining job access to employees.

5. FINDINGS AND RECOMMENDATIONS FOR ANALYZING CONGESTION IMPACTS

Policy Implications. There are three major policy implications that follow from the breadth of business impacts discussed in this paper:

- Current impact studies may be under-estimating the full costs of congestion and the full benefits of investing to reduce future congestion growth, as they fail to capture the full range of business and economic implications generated by congestion growth.
- While the implications of congestion growth can be severe, it is most likely impossible to solve those impacts merely by building more roadway capacity. That is because the interactions of traffic congestion, business location decisions and land use patterns lead to complex interactions that make single dimension policies (such as capacity building) self-defeating. Rather, congestion growth and its adverse economic impacts are most likely to be minimized by policies that combine roadway capacity investments with investment in modal alternatives (for both passenger and freight travel) and pricing schemes that can facilitate the movement of high value and priority freight shipments without undue delay.
- To design and implement such policies, transportation planning and economic impact analysis models must become more sensitive to the different facets of traffic impact and economic consequences. They are:
 - *Mode and Trip Purpose.* There are major differences in the severity of scheduling constraints and reliability concerns for commuting, business worker travel, truck freight deliveries and operation of intermodal facilities. They can differ among various combinations of mode, trip purpose and affected industry/commodity.
 - *Time Periods.* For classes of business-related travel that are most affected by congestion delays and schedule unreliability, there are important differences in the extent of options to modify work shifts and delivery schedules. These options vary by industry depending on abilities to operate and ship during morning, afternoon and/or evening periods.

- *Business Location and Operations Patterns.* For industries that are most dependent on closely integrated supply chains, congestion can affect deployment and use of truck fleets, and that can lead to subsequent changes in the number, location and dispersion of locations for manufacturing and distribution facilities.
- *Intermodal Linkages.* Ultimately, every change in congestion along a segment of the road network is likely to affect access from some areas to airport, marine port or rail intermodal facilities. Conversely, every change affecting the activity at an airport, marine port or railroad facilities is likely to also affect traffic levels to and from it. Thus, congestion impact analysis calls for an intermodal perspective for measuring effects.

Progress to Date. In an attempt to address these key dimensions of impact, all three of the impact studies identified in Section 3 relied on enhanced travel and economic models. They all started out by using regional travel demand forecasting systems to identify the nature of current and potential future congestion. In each case, additional effort was made to separate commuting, business travel and personal trips. These studies also involved additional efforts to separate truck movements from car traffic, and to estimate peak vs. off-peak traffic for key affected areas. Those analyses were also supplemented by special studies that windowed in on conditions affecting (a) highway corridors with particularly high levels of truck movement, (b) key rail and truck corridors providing access to industrial zones, and (c) road corridors serving airport, marine port and/or intermodal rail facilities.

In all three urban regions, the business organization's perspective and the resulting transportation studies emphasized a multi-modal perspective. They recognized that most non-road shipments, whether by air, water or rail, also involve some over-land movement on the highway system at the origin or destination end. Therefore, even for relatively short moves – such as from the airport to a manufacturing plant somewhere in the region, or from a terminal operated by the port to a local warehouse – some part of the region's highway system is used.

The multi-modal traffic modeling perspective used in all three studies was carried forward in their use of the multi-modal economic impact framework (called TREDIS -- Transportation Economic Development Impact System). The importance of this analysis framework is that while it makes use of available local travel demand models and economic models, it imposes a multi-modal data structure to distinguish freight and passenger movements by air, rail, marine and roadway modes of travel. It also distinguishes impacts of transportation projects or scenarios on inter-modal access and connectivity, including access from local roads to airport, marine port and intermodal rail facilities, as well as international border crossings. As a result, this type of analysis framework can reflect impacts of congestion constraints on movement of one mode (e.g., reliability of truck movements through a congested corridor) on the functionality of other modes (e.g., effective volume and service levels for air freight movement at an affected airport).

The resulting information on multi-modal and connectivity impacts was then combined in the analysis framework with information on how various industry sectors of the economy rely on different combinations of transportation modes and inter-modal connections for access to supply

chain and delivery markets. In this way, changes in modal and connectivity performance lead to different impacts on cost and growth opportunities for various industry sectors.

Among the three studies cited here, it is notable that all three required a multi-modal analysis framework because they fundamentally involved issues of road connections to other modes – which could include rail, air and/or port facilities. Yet there was a different combination of local modal issues in each case. For Chicago, a particularly critical issue was capacity and access for truck movements to rail yards and industrial corridors. For Vancouver, a particularly critical issue was capacity of access routes to seaport and airport facilities. For Portland, a particularly critical issue was region-wide truck delivery for warehousing and distribution facilities.

Recognizing Limits to Business Adjustment. A remaining problem that has not yet been well covered in the studies to date is the extent to which businesses can adjust to mitigate congestion through schedule, location and operational changes. It is important for impact studies to recognize that even when businesses shift truck delivery and worker shift schedules to avoid peak congestion, those activity shifts come do have an incremental cost for the business. As noted in the Portland report,

“As congestion becomes a day-long condition, businesses can adjust by further changing their deployment of staff, inventory management and delivery areas. However, such changes affect costs and revenues for both local-serving and trade-oriented businesses. Local-serving businesses either absorb added costs and reduce their profits or pass these costs on to people in the region. Trade-oriented businesses though, can and do move their operations to locations outside the region.”

Recommendations for Future Analysis. Findings from these congestion impact studies indicate the importance of improving future congestion impact analyses to more fully capture the full range of relevant impacts. Beyond the standard benefits of reducing travel time delays, travel distances and safety, it is becoming increasingly important for impact studies to also fully capture effects of:

- Reliability -- recognizing the potential for impacts to hit certain industries that particularly depend on the reliability of specific modes, travel routes and terminals.
- Connectivity – recognizing the potential value of improvements involving local links to interstate highways and intermodal links between road system and airports, marine ports, intermodal rail terminals, border crossings and other key activity nodes;
- Market Access – using analysis methods that can distinguish changes in labor, customer, and material delivery markets, as well as differences in the way that various industries depend on specific modes and corridors to access or serve those markets;
- Multimodal interactions – using methods that can analyze all modes and interactions, such as how a highway expansion or extension project can also affect airport activity, and/or how an airport expansion project can also affect highway traffic levels.

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