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16. Abstract

The demand for infrastructure investment in the Texas-Mexico border region — a demand heightened by the growth in trade resulting from the North American Free Trade Agreement (NAFTA) — has created the need for a comprehensive freight forecasting model. Accordingly, this report presents a methodology useful in forecasting the effects of NAFTA on the demand for freight transportation at the Texas-Mexico border. In developing long-term estimates of future freight-related traffic crossing the border, the methodology employs three steps: (1) an economic analysis of the region, (2) calibration of modal choice models, and (3) an assessment of inventory practices. This methodology is designed to improve upon previous efforts by considering how NAFTA would alter the economic environment in which firms operate, as well as the decisions these firms make regarding modal choice and shipment size. By optimizing the efficient allocation of staff and resources, this methodology could be used to upgrade the operations and infrastructure of the Texas-Mexico border region.

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Research Report Number 1319-4

Research Project 0-1319
Multimodal Planning and the U.S.-Mexico Free Trade Agreement

conducted for the

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

by the

CENTER FOR TRANSPORTATION RESEARCH
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December 1996

IMPLEMENTATION RECOMMENDATIONS

Planners currently lack the means to link U.S.-Mexico trade forecasts with cross-border transportation flows. This causes problems in developing statewide multimodal plans and in ensuring that these plans meet the requirements of those shipping goods as part of the U.S.-Mexico trade pattern. This report seeks to remedy the problem by documenting a three-stage methodology to forecast the demand for different freight transportation modes used in moving surface Texas-Mexico trade. The results are intended for use in optimizing the allocation of staff and resources toward improving the operations and infrastructure of the southern border region, and along NAFTA trade corridors.

The results show:

(1) the development of a theoretical model designed to parallel the decision-making hierarchy typically followed by shippers making modal choice decisions. In the appendices to this report, results based on disaggregated data prepared specifically for the study group by U.S. Customs shows the potential for such modeling;

(2) that implementation of this model will be possible once trade data are presented in more disaggregated forms; and

(3) data currently supplied by customs and commerce departments for public use substantially restrict the development of modal choice models. However, recent developments in harmonizing U.S.-Mexico customs and trade data indicate that more appropriate disaggregated trade data will be available for planning purposes in the near future.

Finally, the report includes a section summarizing modal choice models that shows current use of disaggregated models of the type recommended for implementation by this study report.

Prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

DISCLAIMERS

Robert Harrison
Research Supervisor

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SUMMARY

The demand for infrastructure investment in the Texas-Mexico border region — a demand heightened by the growth in trade resulting from the North American Free Trade Agreement (NAFTA) — has created the need for a comprehensive freight forecasting model. Accordingly, this report presents a methodology useful in forecasting the effects of NAFTA on the demand for freight transportation at the Texas-Mexico border. In developing long-term estimates of future freight-related traffic crossing the border, the methodology employs three steps: (1) an economic analysis of the region, (2) calibration of modal choice models, and (3) an assessment of inventory practices. This methodology is designed to improve upon previous efforts by considering how NAFTA would alter the economic environment in which firms operate, as well as the decisions these firms make regarding modal choice and shipment size. By optimizing the efficient allocation of staff and resources, this methodology could be used to upgrade the operations and infrastructure of the Texas-Mexico border region.

CHAPTER 1. INTRODUCTION

1.1 BACKGROUND

The increase in trade brought about through the North American Free Trade Agreement (NAFTA) has prompted concerns regarding the possible need for transportation system expansion within the Texas-Mexico border area. And while trade forecasting can suggest the scope of such infrastructure needs, previous studies on the transportation impacts of NAFTA have not fully identified the connection between trade forecasts and their resulting transportation impacts. As many transportation planners caution, the failure to acknowledge such a connection can lead to economic inefficiency through a misallocation of planning resources.

This report presents a methodology for forecasting the effects of NAFTA on the demand for freight transportation at the Texas-Mexico border. The methodology's objective is to provide a sound, theoretically based framework that allows planners to analyze the impacts of NAFTA on freight transportation moving between Texas and Mexico. By optimizing the allocation of staff and resources, this methodology can potentially improve the operations and infrastructure of the Texas-Mexico border region.

1.2 OBJECTIVE

The objective of this report is to describe the development of the methodology to forecast freight transportation flows between Texas and Mexico. Following the description on development, this report then recommends how the methodology should be implemented. Finally, areas for future research are identified.

1.3 REPORT ORGANIZATION

Chapter 2 provides relevant background regarding transborder economic activity. It analyzes the economic and transportation systems operating between Texas and Mexico and presents previous forecasting work relating both to NAFTA and to freight demand in general. In this context, Chapter 3 describes the overall purpose and desired functional capability of the methodology described in this report. It includes a definition of the methodological objective and an assessment of the issues that need to be explicitly considered in forecasting freight traffic between Texas and Mexico. These issues give rise to a three-part methodological framework that is designed to parallel the decision-making hierarchy typically followed by those who make modal choice decisions. Chapters 4, 5, and 6 analyze each of these stages to present the theoretical and practical issues relevant to the methodological objective. Chapter 4 discusses the use of interregional input-output analysis to convert macroeconomic forecasts for final demand into estimates of intermediate demand for manufacturers of the final demand products. Chapter 5 develops the background for a freight modal choice model by viewing modal choice from the perspective of an individual shipper, identifying how modal choices and attributes are considered and evaluated to arrive at a decision. Chapter 6 introduces inventory theory in describing how modal demand for a specific commodity will be divided into vehicle trips by mode. Combining these three stages is the goal of Chapter 7, which discusses the data and implementation issues associated with applying this methodology to forecast freight moving across the Texas-Mexico border.

CHAPTER 2. BACKGROUND

Any attempt to develop a methodology for forecasting the freight transportation impacts of the North American Free Trade Agreement (NAFTA) must recognize the historical and economic context of the region, as well as the theoretical context of freight forecasting. This chapter serves to establish both of these contexts, identifying how these factors point to the need for a new forecasting methodology. The first two sections of this chapter summarize some characteristics of the Texas-Mexico border region in terms of transborder economic activity and the traffic and transportation facilities that accompany it. This brief survey is followed by an examination of the methodologies of three published forecasts analyzing the transportation impact of NAFTA. The chapter closes with a review of the more commonly employed techniques in freight demand forecasting, commenting on their strengths and weaknesses within this context.

2.1 TRANSBORDER ECONOMIC ACTIVITY

Even without NAFTA, the trading relationship between the United States and Mexico has been an important source of economic activity for both nations. Mexico is the United States' third largest trading partner, accounting for 7 percent of U.S. exports and imports. The United States is, by far, Mexico's most important trading partner, comprising 70 percent of Mexico's trade (Ref 1). Figure 2.1 shows how U.S.-Mexico trade has grown since 1980. In the early 1980s, this trade was dominated by petroleum and agricultural products; now, manufactured goods comprise the majority of trade, as is shown in Table 2.1.

An important element in the economic relationship between the United States and Mexico is the maquiladora, or maquila. A maquiladora is an in-bond production facility engaged in processing or secondary assembly of imported components for re-export, primarily to the United States. Fifty percent of a maquila's output may now be sold domestically (Ref 2). Maquilas are exempted by the Mexican government from duty on any raw materials or components that are purchased for re-export, and from duty on imported machinery and parts used in export operations.

The maquiladora program started as the Border Industrialization Program (BIP) in 1964, which permitted limited-ownership foreign manufacturers to locate manufacturing plants in industrial parks along the border. BIP's purpose was to promote border industrialization, to stimulate a multiplier effect for Mexican firms which might supply maquilas, and to provide employment for migrant workers in the border communities. Since then, maquilas have become the second largest source of foreign exchange for Mexico, behind petroleum and ahead of tourism (Ref 4). Maquilas now assemble and produce goods for several industries, especially electrical and electronic goods, textiles and apparel, furniture, and transportation equipment (Ref 5). Maquila-related trade has represented an increasing share of trade between the United States and Mexico, as is shown in Figure 2.2.

Mexico now allows 100 percent foreign ownership of maquila plants, an arrangement that has encouraged program involvement for many multinational and foreign companies. Maquilas offer several advantages to U.S. firms, including cheaper labor, lower transportation costs and more reliable transportation services than facilities located in the Far East (Ref 6). In a survey of maquila managers (Ref 7), 93 percent of respondents said that maquila production costs were lower in nearly all areas of production, as labor is substituted for capital whenever possible. Moreover, 55 percent said that maquila logistics costs were also lower, due to cheaper costs in warehousing and order processing. Other countries have set up maquilas in Mexico also, for the additional benefit of proximity to the U.S. consumer market (Ref 4).

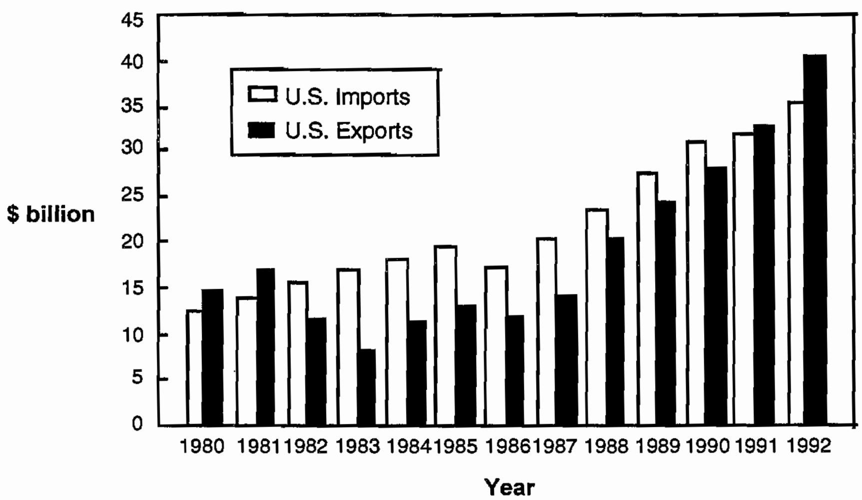


Figure 2.1 U.S. trade with Mexico (Ref 3)

Table 2.1 U.S. imports from and exports to Mexico by commodity group

Commodity Group	U.S. Imports (1992)	% Share	U.S. Exports (1992)	% Share
Electrical machinery	7,991,054,509	22.71	6,902,799,898	17.00
Transport equipment	5,328,583,665	15.14	5,440,337,747	13.40
Miscellaneous	4,384,185,306	12.46	4,306,438,823	10.61
Metal products	3,520,839,784	10.01	4,707,544,998	11.60
Industrial machinery	1,773,982,010	5.04	5,409,614,953	13.33
Minerals	4,644,489,831	13.20	420,124,747	1.03
Agriculture	1,811,878,638	5.15	1,925,134,371	4.74
Chemicals	806,367,340	2.29	2,766,075,944	6.81
Apparel	1,959,929,756	5.57	955,132,600	2.35
Food	944,121,170	2.68	1,949,625,277	4.80
Instruments	1,230,748,869	3.50	1,385,407,582	3.41
Rubber & plastics	355,050,683	1.01	1,411,747,065	3.48
Unclassified	–	0.00	1,511,507,235	3.72
Refined petroleum	320,412,214	0.91	922,968,398	2.27
Textiles	112,505,294	0.32	583,017,799	1.44
Total	35,184,149,069	100.00	40,597,477,437	100.00

Source: Reference 3. All figures in dollars.

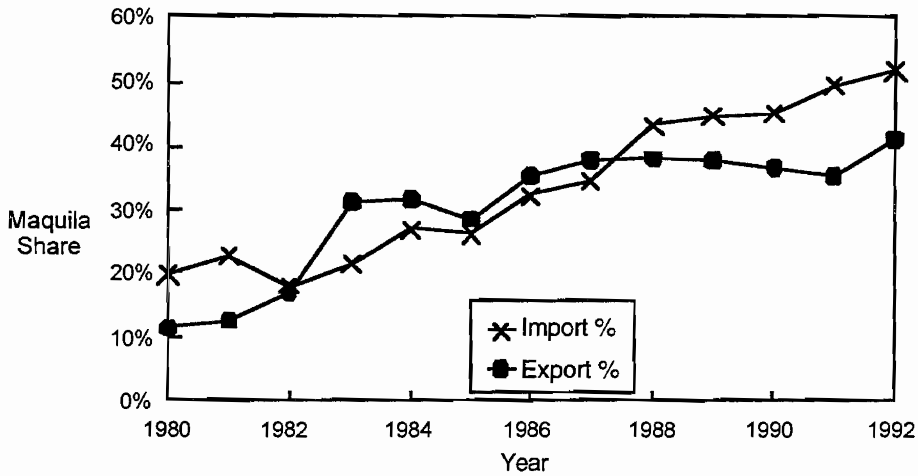


Figure 2.2 Maquila trade as a share of U.S. trade with Mexico (Ref 3)

In 1965 there were twelve maquilas in Mexico. The program grew along the border, and expanded to interior Mexico with BIP's re-authorization in 1972. When the peso collapsed in the mid-1980s, real Mexican wages dropped, making the nation more attractive to foreign manufacturers. As a consequence, maquiladoras flourished. In 1984, 670 maquilas employed around 200,000 Mexicans (Ref 6). By November 1993, this had increased to over 2,000 maquilas, employing over 460,000 Mexicans (Ref 8). This remarkable growth is expected to continue, with maquila output expected to increase between 8 and 12 percent annually (Ref 7).

This growth in maquilas — and in U.S.-Mexican trade — came in spite of tariffs and other economic restrictions on goods transported between the two countries. The promise of NAFTA is that it will increase trade between the two nations even more. NAFTA was ratified by the United States Congress in the fall of 1993, and was implemented by Canada, the United States, and Mexico on January 1, 1994. The agreement created a free-trade zone encompassing the three signing nations with dramatically reduced tariffs and much greater corporate freedom for multi-national firms. It served as a follow-up to the Canada-U.S. Free Trade Agreement (FTA), implemented in 1988, which liberalized trade between those neighboring countries. At the start of its negotiations, NAFTA included only Mexico and the United States as partners. However, Canada was added during drafting, and other nations — such as Chile — are being considered for inclusion (Ref 9). NAFTA went beyond FTA in several aspects, expanding investment and trade liberalization, adding protection of intellectual property rights, imposing rules against distortions to investment, and considering transportation services in its terms (Ref 10).

2.2 TRANSPORTATION ACTIVITY

As of 1994, 90 percent of bilateral trade between the United States and Mexico traveled by land (motor carrier or rail), with the remainder traveling by air, sea, or pipeline (Ref 11). To understand transportation activity in the border region, it is important to again consider the maquiladoras, which have had a major impact on transborder flows.

The percentage of truck crossings at Texas border crossings associated with maquiladoras ranges from 79 percent at El Paso and 77 percent at Hidalgo to 60 percent at Brownsville and 38 percent at Laredo (Ref 6). As production technology has become increasingly automated and as more maquiladoras have opened in the border region, a scarcity of inexpensive, skilled labor has developed at the border, especially since the maquila labor force is highly unstable and transient. Consequently, there has been an increase in maquiladora activity in Mexico's interior, especially around Mexico City, to take advantage of the availability of qualified workers (Ref 6). This trend toward interior maquilas has accelerated, as firms strive to take advantage of the more abundant, more stable, less expensive, and better educated laborers. Up to 15 percent of maquilas are now located in nonborder states (Ref 4). As maquilas continue to grow in importance in the Mexican economy, they will impose greater transportation demands on Mexico's infrastructure, not only at the border region, but also on corridors and arteries in interior Mexico.

To examine the movement of goods between Mexico and the United States, three components are considered. First, current trade patterns across the border are examined. Second, the modal infrastructure between the two countries is briefly described in order to identify the availability and accessibility of modal options. Finally, the transportation-related provisions included in NAFTA are addressed.

2.2.1 Goods Movement

Freight movement between the United States and Mexico is currently dominated by motor carriers, which ship 85 percent of goods in and out of the border region (Ref 6). For U.S. exports to Mexico, 90 percent of freight (in value) was transported by land, either by rail or motor carrier; the rest was almost evenly divided between air and maritime modes. Sixty-one percent of U.S. imports were by motor carrier, with 18 percent by rail, 15 percent by sea, and the remainder by air, pipeline, and other modes (Ref 3).

Data obtained from the U.S. Customs Service helps to clarify northbound trading patterns that exist between Mexico and the United States (see Appendix A). Table 2.2 shows that El Paso and Laredo are the most commercially significant of the five ports of entry. However, Laredo is the most multimodal port, as nearly thirty percent of its shipments are transported by nonmotor carrier modes. Eagle Pass' traffic is also multimodal in character, although its volume is significantly less than other ports along the border. While the vast majority of rail shipments involve transportation equipment, motor carriers carry a diversified group of commodities, as shown in Tables 2.3 and 2.4.

Four of the five ports of entry are dominated by traffic originating from neighboring cities and towns, as might be expected from maquiladora-based traffic. Brownsville derives most of its traffic from its twin city Matamoros, Eagle Pass from Piedras Negras, Saltillo, and Ramos Arizpe in neighboring Coahuila de Zaragoza, El Paso from Juarez, and Hidalgo from Reynosa. Laredo is the primary port of entry for cities in Mexico's interior, such as Mexico City and Monterrey, and does not have nearly as much traffic from its twin city, Nuevo Laredo. Appendix A shows the major cities of origin for shipments passing through each of the five Texas ports, with the observed modal split at each port.

Table 2.2 Transport mode by Texas port of entry for northbound freight

Port of Entry	10 Maritime	20 Railroad	30 Truck	40 Air	50 Mail	Total
El Paso	0.1	92.7	7,880.4	59.1	0.1	8,032.4
Laredo	2.8	2,377.6	5,648.5	1.3	0.0	8,030.3
Brownsville	0.1	168.9	2,385.7	0.0	0.0	2,554.7
Hidalgo	0.0	0.0	1,527.9	0.2	0.0	1,528.1
Eagle Pass	0.0	204.7	277.4	0.0	0.0	482.1
Total	**3.0**	**2,843.9**	**17,719.9**	**60.6**	**0.1**	**20,627.7**

Source: United States Customs Service. Figures are in millions of dollars of value annually.

Table 2.3 Top commodities carried by railroads from Mexico to Texas

Chp	Commodity	Brownsville	El Paso	Eagle Pass	Hidalgo	Laredo	Total
87	Non-Rail Vehicles	83.5	0.0	98.1	0.0	1,947.7	2,129.3
84	Mechanical Machinery	0.0	0.0	12.0	0.0	109.5	121.5
22	Beverages	2.9	0.0	40.7	0.0	62.8	106.4
79	Zinc	0.0	10.2	17.9	0.0	73.0	101.1
73	Iron and Steel Articles	1.7	0.3	3.5	0.0	78.1	183.5
28	Inorganic Chemicals	61.9	3.4	4.0	0.0	11.9	81.2
74	Copper	0.3	41.3	0.0	0.0	0.0	41.6
98	Special Classifications	9.5	0.7	0.1	0.0	16.0	26.2
72	Iron and Steel	0.0	0.6	19.9	0.0	3.3	23.8
48	Paper	0.0	16.7	0.0	0.0	2.6	19.4
	Top Ten	**159.7**	**73.1**	**196.2**	**0.0**	**2,304.9**	**2,733.9**
	Other	**9.5**	**19.7**	**8.5**	**0.0**	**72.4**	**110.1**
	Total	**169.2**	**92.8**	**204.7**	**0.0**	**2,377.3**	**2,844.1**

Source: United States Customs Service. Figures are in millions of dollars annually.

Table 2.4 Top commodities carried by motor carriers from Mexico to Texas

Chp	Commodity	Brownsville	El Paso	Eagle Pass	Hidalgo	Laredo	Total
85	Electrical Machinery	1,286.5	4,278.3	89.8	664.2	1,259.5	7,578.2
84	Mechanical Machinery	127.8	682.1	5.8	120.6	930.5	1,866.7
87	Non-Rail Vehicles	205.8	221.4	11.0	56.5	547.5	1,042.3
90	Precision Instruments	128.6	532.5	0.0	116.4	219.6	997.2
98	Special Classifications	130.7	409.9	10.6	95.1	158.9	805.3
62	Non-Knitted Apparel	16.3	541.5	58.3	91.0	43.1	750.2
94	Furniture	10.0	499.6	9.4	7.2	124.8	651.0
39	Plastics	36.2	57.4	6.1	21.2	156.8	277.7
73	Iron and Steel Articles	10.3	20.3	20.5	9.6	210.0	270.7
9	Coffee and Spices	0.2	1.3	0.0	0.3	234.0	235.8
	Top Ten	**1,952.5**	**7,244.5**	**211.4**	**1,182.1**	**3,884.6**	**14,475.0**
	Other	**434.7**	**621.8**	**65.8**	**346.0**	**1,765.6**	**3,233.9**
	Total	**2,387.1**	**7,866.3**	**277.2**	**1,528.0**	**5,650.1**	**17,708.8**

Source: United States Customs Service. Figures are in millions of dollars.

2.2.2 Infrastructure

The movement of goods between countries will reflect the quality of the infrastructure in each of those countries, as well as the quality of linkages between them. Owing to Mexico's inland transportation infrastructure and its topography, for example, most freight traffic within Mexico travels on well-defined, north-south corridors (Ref 3). Seventy percent of the trade goes through Texas (Ref 12). Similar to the disparity between the two countries' economies, the infrastructures of Mexico and Texas are in markedly different states of condition, technology, and access (Refs 13, 1).

Highway: The Texas highway system includes over 480,000 kilometers of rural and urban roads, although not many of these roads will be significantly impacted by trade between the U.S. and Mexico. Some highways that are directly affected by trade with Mexico include IH-35 from Laredo to Dallas, US 59 from Laredo to Houston, and IH-10 from El Paso. Owing to the rehabilitation and expansion needs prompted by increases in truck traffic, Texas roads require a significant amount of improvement. The Texas Department of Transportation assessed the cost of upgrading the highway network in the vicinity of the border to four-lane divided highways within thirty years at roughly $2 billion. Depending on how trade-related traffic increases, additional maintenance needs could increase this figure by another $100 million.

Compared with the United States' interstate system, Mexico's highway network is primitive. Of 240,000 kilometers of roads, only one-third are paved, and of paved roads, less than 6 percent have four or more lanes. In efforts to improve its network, Mexico has encouraged construction of four-lane toll roads. As of 1992, however, these constituted just over 1 percent of the network. Moreover, the toll roads have not been successful in diverting traffic from poorer quality rural and state roads because the tolls on the federal highway system — about $20 for the 120-mile trip from Monterrey to the border — are among the highest in the world in absolute terms (Ref 14).

Rail: Four of the seven Class I railroads serve Texas gateways to Mexico; these include Union Pacific, Burlington Northern, Southern Pacific, and the Atchison, Topeka and Santa Fe. They provide service to five gateways in Texas: Brownsville, Laredo, Eagle Pass, Presidio, and El Paso. Recent mergers in the railroad industry may have changed the degree of service in the border region. Mexico's rail network consists of 26,000 kilometers of varying caliber served by a federal carrier, Ferrocarriles Nacionales de México (FNM). Most track has been standardized such that Mexican and U.S. locomotives can interline into each other's system. However, Mexico's system is well behind the United States in terms of technology and maintenance. In 1992 President Salinas said that FNM was "in no condition to provide support for the Mexican economy's competitiveness." Current operating speeds for FNM trains are below those found in Mexico in the 1930s, and FNM's locomotive fleet is in need of upgrading (Ref 11).

Air Transportation: Air transportation has been growing more rapidly than any other mode of transport between the U.S. and Mexico. Between 1987 and 1992, airborne U.S. imports from Mexico increased from $409 to $806 million, while exports jumped from $692 million to $2.15 billion. Because of the high cost associated with air shipments, they are often directed as close to the destination of a major cargo hub as possible. Consequently, of the 26 Texas airports with commercial service, the most important air cargo airports are not on the border (i.e., Dallas-Fort Worth and Houston Intercontinental).

Mexico has been pursuing private investment in its airport system, and no longer has a state-owned airline. Mexico City has the busiest airport in the country, and has been operating with aircraft volumes much heavier than for which it was originally designed. Aeropuertos y Servicios Auxiliares, Mexico's airport agency, has been attempting to divert traffic, especially air cargo, to feeder airports to ease congestion. However, the highway network connecting Mexico City to its reliever airports is considered more daunting than the congestion at Mexico City.

Maritime Transportation: Six of the fifty largest ports in the United States in 1990 were in Texas, including Houston, Texas City, Corpus Christi, Port Arthur, Beaumont and Freeport. Houston and Galveston are among the 25 largest U.S. ports in handling containerized traffic. In trade with Mexico, petroleum is the largest source of traffic for ports, accounting for 85 percent of the tonnage handled at the six ports listed. Texas ports claim to have slack capacity ranging from 10 to 30 percent.

Mexico has twenty maritime ports, split between its Pacific and Gulf coasts, which handle nearly 90 percent of Mexico's foreign trade. Despite the importance of the maritime sector to the Mexican economy, Mexico's ports are generally substandard. Poor intermodal connections, a lack of containerization facilities, labor problems and other factors have encouraged shippers to use other modes. In fact, 60 percent of Mexican companies cited Mexican port conditions as a reason they choose to ship through Houston rather than through Veracruz (Ref 13).

Border Crossing: Shippers have historically viewed the border and its clearance procedures as a considerable hindrance to on-time delivery of shipments. Different authors attribute problems to different parties, such as "a lack of documentation or poor documentation preparation by the Mexican exporter," "tie-ups at the border related to processing and customs, particularly for intermodal traffic," and "less developed transportation system and logistics management practices in Mexico" (Refs 15, 16, 17).

Texas is the only state on Mexico's land border to have a water crossing. As of 1993, there were 34 existing or proposed border crossings, not all of which are suitable for heavy trucks. In addition, some of these bridges connect directly into border cities, resulting in additional traffic congestion and environmental degradation in those cities, and accelerated depreciation of the supporting infrastructure.

2.2.3 NAFTA Provisions

This section highlights some of NAFTA's provisions regarding truck transportation, standards, and investment rules (Refs 10, 18).

Truck Transportation: NAFTA will allow trucks greater flexibility of movement. Prior to NAFTA, Mexican carriers were restricted from operating outside of the border commercial zones. Only two of these zones extended more than 40 km into the United States. NAFTA provides considerably expanded access to carriers on both sides of the border. In 1995 U.S. truck drivers could make cross-border deliveries into the U.S. border states. By 2000, drivers from any NAFTA country will be allowed to operate anywhere within any other NAFTA country.

Standards: NAFTA established a Land Transportation Standards Subcommittee in order to establish compatible vehicle standards, in terms of weights, dimensions, inspections, and emissions. As this harmonization of standards improves, this will enhance the ability of trucks to operate internationally. Some disputes, such as those regarding safety standards for drivers, have yet to be resolved.

Investment: NAFTA also has key ownership provision for transportation providers. By the end of 1995, Mexico permitted up to 49 percent United States ownership in trucking firms which provide international cargo services. This percentage will rise to 51 percent by the year 2001, and to 100 percent by the year 2004. There is no change in investment rules regarding rail services. Any NAFTA investor will be able to market, construct, and own terminals and track in Mexico. Existing interlining agreements between FNM and U.S. railroads are still in effect, and crews still have to be changed at the border. Mexico will also allow U.S. and Canadian firms to maintain wholly owned investments at Mexican ports to handle their own cargo.

2.3 NAFTA FORECASTS

In the United States, NAFTA has spawned a great deal of discussion concerning employment gains or losses. This concern arose because of the uniqueness of the border between Mexico and the United States. Nowhere else in the world do two neighboring countries have such disparity in economic development, labor force quality, and average wage levels. Because of the cheaper labor found in Mexico, opponents to NAFTA have argued that many corporations will use the agreement to relocate manufacturing or assembly operations into Mexico and save in labor costs. Opponents argue that the consequence of such an exodus would be a significant loss of high-wage American jobs. Proponents counter that these labor savings would translate into a lower cost of living on both sides of the border, an increased real income, and an allowance for market growth for U.S. companies. Increased demand for American products would create employment opportunities sufficient to offset any losses due to the relocation of production facilities. The stakes raised in the political debate over NAFTA ratification in the United States created fertile ground for new trade forecasts and methodologies.

Along with this renewal of interest in trade forecasts, there has been growing interest in recent years in infrastructure maintenance at the border region, especially in Texas, which has forecast needs for $1.2 billion in infrastructure investment at its border (Ref 5). Increases in truck traffic and changes in maximum truck weight limits have resulted in congested and run-down roads on the U.S.-side of the border, causing concern for both government officials and transportation planners. In an era of fiscal restraint at all levels of government, it is critical for funds to be invested where the benefit-cost ratio is maximized.

The result of these trends has been a need for a forecasting methodology which will be able to reflect both the trade effects of NAFTA and the resulting transportation impacts, while understanding and acknowledging their direct linkages. Dozens of forecasts have attempted to assess NAFTA's impacts for different industries or industry groups. However, there have been few attempts to model the transportation impacts relating to NAFTA.

This section analyzes three studies designed to forecast the transportation impact of NAFTA: the Laredo Development Foundation (1992), the Federal Highway Administration (1993), and the Texas Transportation Institute (1994). To provide a context for the transportation forecasts, a NAFTA forecast by the World Bank (1992) is first presented (Ref 5). This analysis was developed using historical data compiled by a World Bank report which studies the effects of economic liberalization on trade. According to these forecasts, one could predict an 11.2 percent annual real growth rate in trade. In the absence of NAFTA, this growth rate would only be 7.9 percent. From a base year 1989 exports level of $32.9 billion, NAFTA would have resulted in $62.2 billion in U.S. exports and $78.1 billion in imports by 1995. The three studies are discussed in turn hereafter.

2.3.1 Laredo Development Foundation (1992)

In 1992 the Laredo Development Foundation issued a report assessing the potential impacts of NAFTA on the port of Laredo. These impacts focused primarily on highway and employment impacts, by comparing two scenarios: one without implementation of NAFTA, and one with NAFTA. The study's forecasts were based on a fixed percentage of growth per year, employing aggregate economic data compiled from 1987 to 1992, with a forecast horizon from 1994 to 2000, as detailed in a 1992 report (Ref 19).

In generating its forecasts, the foundation made two basic assumptions. First, Mexico's economic growth rate was expected to maintain the remarkable levels it showed between 1987 and 1992. This assumption was based on several factors, including Mexico's declining inflation rate, an increase in foreign investment in Mexico, a reduction in foreign debt, and an increase in financial savings. Second, the pre-1992 increases in exports, imports and truck trips through Laredo were expected to continue through 2000 and beyond. This was based on Laredo's location on the primary trade route between interior Mexico and the industrial heartland of the U.S., and its established modal links and intermodal facilities.

For the "without NAFTA" scenario, the paper proposed that the United States and Mexico would continue to import from each other at the same — if not higher — growth rates as observed in 1987-1992. Differential rates of growth were assumed in the number of truck shipments between northbound and southbound truck shipments. Northbound truck shipments were expected to increase at a slower rate than U.S. imports from Mexico because much of that trade growth was expected to come in the import of products transported by sea, such as petroleum. Southbound truck shipments were expected to increase at a slightly higher rate than U.S. exports, because of two assumptions: 1) Laredo's share of U.S. export shipments would continue to increase, and 2) the number of maquiladora plants in northeastern Mexico was increasing.

The "with NAFTA" scenario assumed transitional implementation of NAFTA. Since tariffs are gradually phased out over a fifteen-year period, the foundation estimated that, by the year 2000, 75 percent of tariffs would be eliminated. With regards to imports and exports, the report assumed that the growth in exports would taper off after a few years and imports would accelerate, to reflect Mexico's need for additional capital as production capacity increased. Exports would continue to increase as a result of an increase in Mexico's aggregate purchasing power, as a multiplier effect of the higher-wage jobs which would be coming into the area.

Table 2.5 Laredo Development Foundation growth rate estimates

	Annual Actual Growth (1987-1992)	Without NAFTA Annual Growth (1994-2000)	With NAFTA Annual Growth (1994-2000)
Exports	28%	22%	34%
Imports	16%	16%	27%
Total Trade	22%	19%	31%
Southbound Truck Shipments	28%	24%	30%
Northbound Truck Shipments	8%	12%	25%

Source: Reference 19

The forecasts resulted in aggressive estimates of growth for both imports and exports through Mexico, as is shown in Table 2.5. Without NAFTA, total trade was estimated to grow at an annual rate of 19 percent, with exports growing more quickly than imports. With NAFTA, the estimated annual growth rate was an astronomical 31 percent. The corresponding trucking impacts were also remarkable, with loaded northbound truck shipments increasing an estimated 25 percent per year under NAFTA.

This study suffers in that its estimates rely almost entirely on a trendline analysis, projecting future trade and traffic volumes from aggregate figures of past activity. This implies that the factors which caused growth in trade from 1987-1992 would be capable of creating a similar growth rate in trade in future years. This is wrong in two areas. First, one major contributor to the growth in trade between 1987 and 1992 was the strengthening of the peso after a period of devaluation in the early 1980s. It is unlikely that the peso could continue to grow to stimulate increases in trade volumes at the rates previously observed. Second, NAFTA will alter the structure of the economic relationship between the two nations, changing capital formation, industrial production, and distribution patterns. Consequently, it would be imprudent to presume that NAFTA trade patterns would mimic those found in 1987-1992.

2.3.2 Federal Highway Administration (1993)

Sections 1089 and 6015 of the Intermodal Surface Transportation Efficiency Act of 1991 provided funding for conducting a study of border crossings among the nations in the NAFTA agreement. The Federal Highway Administration (FHWA) completed this study in 1993, and it analyzed three different border regions, including the land border between the United States and Mexico.

The study relied on a static, national-level econometric model called INFORUM to address the economic implications of an implemented NAFTA. INFORUM is macroscopic in nature, which prevented the model from capturing either regional or local effects of NAFTA or the agreement's effect on individual modes. It employed two major assumptions in order to project traffic flows through ports of entry on the border: a constant transportation mode share and an unchanged commodity group trade flow. The first assumption was based on informal input from shippers and carriers. The second assumption implies that each gateway's share of trade in a given commodity group would remain unchanged. Consequently, each gateway's traffic would increase according to the rate of growth in commodities using that gateway.

Table 2.6 summarizes the study's forecasts for the years 1992-2000. One will note that the anticipated growth rates in trade volume through South Texas, of which the most prominent port of entry is Laredo, are considerably more conservative than those of the Laredo Development Foundation study. This reflects that the FHWA study explicitly considered commodity demand in developing its estimates. The FHWA study, however, failed to address the structural impact of NAFTA on decisions of production location and distribution patterns. The macroscopic nature of INFORUM would tend to conceal the firm-level decisions to relocate production capacity in order to adapt to the different economic environment created by NAFTA. Moreover, the FHWA study was not mode-specific, so it did not generate traffic estimates.

Table 2.6 Federal Highway Administration growth rate estimates

	No NAFTA	NAFTA Tariff removal only	NAFTA Tariff and barrier removal
Exports	6.1-6.4%	5.4-5.7%	6.5-6.9%
Imports (S. Texas)	5.2%	8.0%	10.4%
Imports (W. Texas)	4.3%	7.4%	9.7%

Adapted from: Reference 20

2.3.3 Texas Transportation Institute (1994)

With the cooperation of the Texas Department of Transportation, the U.S. Department of Transportation and the Federal Highway Administration, the Texas Transportation Institute (TTI) conducted a study to determine the impacts of NAFTA and expanded U.S.-Mexico trade on the Texas highway infrastructure. The study's intent was to examine how the Texas economy and Texas roads would be affected by NAFTA-related trade, and to identify any relationships that existed between international trade flows, economic activity, and truck flows across the border and throughout the Texas highway system. This forecast is detailed in Luker, Cuellar, Memmott, Danave, Steffel, and Stolp (Ref 21).

TTI estimated the number of truck trips for a given Texas county and year by using multiple regression models to estimate values for the mean annual average (MAADT). Models were calibrated using annual average daily traffic (AADT) counts from counting stations along all major highways in Texas, both south-to-north and west-to-east, for the years 1986 to 1992. Each year had 331 observations, to represent a cross-section of urban and rural highways throughout the state, as well as border crossing points. The models were primarily empirical and lacked any explicit theoretical basis.

The first two models provided estimates for MAADTjt for each counting station j in year t, for a sample of 331 counting stations from 1986 to 1992. The first model examined the effects of aggregate U.S.-Mexican trade and population, regional, and area effects on MAADTjt. Total trade volume was found not to be statistically significant, whereas the county population and dummy variables representing each region and area were largely found to be significant. The second model emphasized network effects, including variables representing the county's relative distance from the border and the number of border crossings per year and dropping variables representing U.S.-Mexico trade. Variables representing activity at individual border crossings were not statistically significant, but the logarithm of the distance between the county and the border proved significant, as did the county population variable.

The third and fourth models provided estimates for MAADT by highway k for each of twenty major highway routes for county j in year t. The third model was similar to the first one, except that it was modeled individually for each highway segment, and excluded dummy variables to capture regional effects. However, neither of the trade variable parameter estimates was found to be significant for any of the highway segments. The fourth model was identical to the second model except that it provided estimates at a highway-specific level. As was true for the second model, the logarithm of the distance was statistically significant, but there were no other general patterns of significance for any of the other variables.

It is worth noting that these first four models found little relation between truck traffic volumes and trade between Texas and Mexico. This runs against intuition as well as the results indicated in the Laredo Development Foundation and FHWA studies. However, these models were calibrated with data from counting stations around the state, many of which are located far from the Texas-Mexico border, and without direct access to border cities.

The study also included a fifth model, which estimated the annual number of border crossings by port of entry for six Texas border cities — El Paso, Presidio, Del Rio, Eagle Pass, Laredo, and Brownsville — based on trade between the U.S. and Mexico. Since this model most closely addresses the issue raised in this paper, it is discussed in greater detail. The model equation was:

$$\ln ATBX_{bt} = \beta_{b0} + \beta_{b1} \ln USXTM_t + \beta_{b2} \ln USMFM_t + u_{bt} \tag{2.1}$$

where $ATBX_{bt}$ = the number of truck crossings at border crossing b in year t

$USXTM_t$ = U.S. exports to Mexico in year t

$USMFM_t$ = U.S. imports from Mexico in year t

u_{bt} = residual term

β_{bj} = regression coefficients ($j = 0, 1, 2$)

One would expect that there would be little transborder Texas-Mexico truck traffic independent of international trade; therefore, β_{b0} should be positive, yet small. Moreover, an increase in trade between the U.S. and Mexico — whether it is northbound or southbound traffic — should increase the number of annual border (though not necessarily truck) crossings; therefore, both β_{b1} and β_{b2} should be positive. In Table 2.7, one can see that neither hypothesis is fully confirmed. The values for β_{b1} and β_{b2} at Laredo and El Paso are greater in magnitude than those at the other border cities, confirming that the majority of Texas-Mexico trade crosses the border through these two ports. However, many other regression estimates do not make sense, and were not thoroughly examined by the authors. For example, why should truck traffic through Presidio increase when trade between Texas and Mexico decreases, as β_{b1} and β_{b2} would indicate? Why do truck volumes through Eagle Pass and Brownsville seem so insensitive to the value of imports and exports crossing the border?

Table 2.7 Regression results from TTI study

Variable	Label	El Paso	Presidio	Del Rio	Eagle Pass	Laredo	Brownsville
Intercept	b_{b0}	-3.583*	8.984*	4.376*	8.057*	1.246*	11.645*
U.S. Exports	b_{b1}	-2.531*	-0.034	0.426*	0.075*	-1.253*	0.499*
U.S. Imports	b_{b2}	7.316*	-0.015	1.303*	0.663*	4.612*	-0.337*
Goodness of Fit	R^2	0.80	Not listed	0.91	0.95	0.91	0.65

(*) denotes a statistically significant coefficient value. Adapted from Table 4-6, Reference 21

In evaluating the transportation impact of NAFTA on the Texas highway infrastructure, the TTI study did not apply economic forecasts for growth in exports and imports to estimate transborder traffic, as the FHWA study did. Instead, TTI estimated the costs of highway maintenance for different trade growth scenarios. Therefore, no specific forecasts for growth in transportation as a result of NAFTA were generated in the study.

Like the Laredo Development Foundation and FHWA studies, the TTI report did not attempt to model how firms might respond to the removal of trade and tariff barriers in a way different from pre-NAFTA patterns. It reflected a view that the trade patterns of the past will persist even with a removal of trade and tariff barriers between the U.S. and Mexico. Moreover, equation (2.1) considers the volume of truck traffic to be strictly a function of aggregate trade flow, without considering factors which may cause freight to be transported by rail or other modes. In summary, the TTI study lacks the ability to isolate and identify those factors which will contribute to increases in truck traffic, as it is connected neither to economic modeling nor to modal choice modeling processes.

2.3.4 Synopsis

The three reviewed studies share some common criticisms in developing forecasts of NAFTA's transportation impacts. First, these studies do an inadequate job of considering how NAFTA might cause firms to restructure their operations to take advantage of lower trade barriers.

As the cost of crossing the border decreases in terms of both tariffs and delays, more firms would be likely to switch various manufacturing operations across the border in order to improve production costs. The FHWA study did a better job than the other two studies in considering the effects of NAFTA on growth in consumer markets, but it neglected to consider how firms might respond to NAFTA in production decisions regarding intermediate goods.

The studies also fail to consider how modal choice decisions are made in this context. The Laredo Development Foundation and TTI studies each treat modal choice as an aggregate decision based strictly on the volume of total trade, without regard to system capacity, commodity characteristics, or changes in modal technology over time. The FHWA study did marginally better than the other two studies by considering modal choice to be a function of the commodity; however, it also assumed that modal share would remain constant over time. Since NAFTA may affect production strategies at the firm level, it also might have an effect on distribution and logistics strategies, meaning that modal choice should be explicitly addressed within a modeling framework.

These models are also insensitive to the instability of the Mexican economy. Trade between the United States and Mexico has exhibited considerable fluctuation over the past twenty years based on the strength or weakness of the peso. Despite this, none of the three models was tested for sensitivity to exchange rates. The studies also did not explicitly consider how innovations in transportation and information technology have transformed the modal choices that are available to shippers. In these areas and many others, the models lack a mechanism to respond to changes in the economic and industrial structure which may significantly impact trade volumes.

The studies' principal "strength," with the possible exception of FHWA's INFORUM model, is in their apparent simplicity. They provide comparatively inexpensive estimates of the impacts of NAFTA on transportation across the border with limited data input needs. However, the difference between the estimates for the growth rates suggests that these models are comparatively imprecise and inaccurate as well. Their failure to more explicitly consider the impact of NAFTA on firm behavior in production and modal choice decisions contributes to their inability to be used effectively for long-range planning purposes.

2.4 FREIGHT DEMAND FORECASTING TECHNIQUES

Many different techniques have been proposed and tested for modeling freight demand. This section will review some of the principal classes of models used in predicting freight modal split, describing their basic theoretical underpinnings and identifying some studies which have employed those techniques. These models are divided into two broad headings: econometric methods and network-based methods. Survey articles used to compile this section include Smith (Ref 22), Allen (Ref 23), Winston (Ref 24), Oum, Waters, and Yong (Ref 25), and Abdelwahab and Sargious (Ref 26).

2.4.1 Econometric Methods

Econometric methods attempt to identify and analyze cause-and-effect and correlative relationships between freight demand and various factors. They require the development of mathematical models which are calibrated according to previously collected data. These models may be validated for predictive accuracy by applying the model to a different sample. Three classes of econometric methods will be discussed in this section: aggregate, system-aggregate, and disaggregate.

Aggregate Methods: Aggregate models are macroscopic in nature, measuring the average behavior of individuals or shippers. They examine modal trends on a system-wide perspective, looking for broad correlations between easily measured aggregate variables and transportation demand. These models require that observations be aggregated, ideally such that the within-group variance of key attributes is less than the between-group variance. This aggregation could be according to any attribute, such as origin, destination, shipment size, firm size, or commodity.

The first type of aggregate methods can be classified as macro econometric modal split models. These models seek to express modal share as a function of the differences of attributes of each of the modes, such as price and travel time. For examining the modal split between two modes I and j, the model might be specified as:

$$\ln \frac{S_i}{S_j} = a_0 + a_1 \ln \frac{P_i}{P_j} + \sum_{k=2}^{K} a_k \left(X_{ik} - X_{jk}\right) \tag{2.2}$$

where S_m = market price of mode m

P_m = price of mode m

X_{mk} = value of attribute k for mode m

a_k = regression coefficient for attribute k

Two formulations of such a model were used to predict market share between rail and truck for a set of domestic shipments in the U.S. across various commodities from 1956 to 1960: a ratio-based dependent variable as shown in equation 2.2, and one based on the tonnage values for each mode (Ref 27). Several different combinations of dependent variables — such as freight rates, transit times, and ratios of these attributes — and several levels of disaggregation were examined. Surti and Ebrahimi (Ref 28) regressed motor carriers' market share against distance of shipment and shipment size. Data obtained from the 1963 Census of Transportation were divided into 24 commodity groups, with regressions developed for each commodity group. Of three models that were attempted, the best-fitting model was based on a linear regression of distance and shipment size. Jelavich (Ref 29) used two equations to regress relative modal shares for a three-mode case of rail, motor carrier, and "other." Levin (Ref 30) incorporated utility maximization by using a multinomial logit model to examine the effects of rates, transit time, and transit time reliability on modal split over data aggregated by weight blocks. German and Babcock (Ref 31) estimated an index number reflecting the change in rail's market share between 1980 and 1989. They estimated this index against a price ratio, a service ratio, and dummy variables for each year in the study.

Macroeconometric modal split models have reported strong correlations between predicted and actual market share during calibration. However, these models lack theoretical grounding in the profit-maximizing behavior of the firm. Another school of models, called neoclassical economic aggregate models, addresses this shortcoming by explicitly addressing firms' production cost functions. By characterizing a firm's production function as translog in nature, the modal share equation becomes:

$$S_i = a_i + \sum_s A_{ij} \ln P_s + \sum_j B_{ij} \ln q_j + \sum_h C_{ih} \ln w_h + D_y \ln Y \qquad (2.3)$$

where q = shipment characteristics vector

w = factor prices vector

Y = output

a, A, B, C, D = estimated regression coefficients

Oum (Ref 32) modeled demand for freight as an intermediate input in the production process. Four models were developed using translog cost functions to estimate modal shares for rail, highway, and maritime modes in Canada. Lewis and Widup (Ref 33) also used translog cost functions to estimate elasticities of demand for truck and rail. Friedlaender and Spady (Ref 34) built their work from this framework, defining modal prices as a function of both freight rates and a firm's inventory cost function.

A special case of aggregate models is called the direct demand technique, where the actual modal demand is estimated as a function of macroeconomic variables. It is commonly used to calculate intercity freight demand for a given city-pair. Sloss (Ref 35) estimated tonnage shipped by for-hire motor carriers with a logarithmic, multiplicative model incorporating average revenue per ton, levels of economic activity, and a commodity-specific average revenue by ton.

Aggregate methods are generally successful at identifying correlations between independent and dependent variables, but are generally unable to indicate causality at either the shipment or shipper level. It is important to note, however, that these studies have analyzed freight movements in comparatively static markets. However, the process of NAFTA implementation and the evolving economic relationship between Texas and Mexico create a freight market which cannot be described as static in any sense. Accordingly, aggregate static methods would likely perform poorly in evaluating the transportation impacts of NAFTA.

System-Aggregate Methods: Another set of econometric techniques can be labeled as system-aggregate methods. These are implicitly multiple-step models which treat freight modeling as a process of interaction between sequential stages of analysis. System-aggregate methods usually view freight transportation not as a movement of individual shipments, but as an array of flows, akin to how urban passenger transportation planning is conventionally viewed.

For example, Mathematica (Ref 36) developed a five-stage process to forecast the amount of tonnage of commodity k transported during time period t from I to j on mode m. First, estimates for movements of freight tonnage over t were generated as a function of population and economic variables. Then, for t, freight movements from I to j were estimated. Tonnage estimates are estimated for each i-j pair, each commodity k and mode m over t based on commodity and modal characteristics. Next, twin functions were developed to estimate the tonnage of commodity k transported from I to j and the amount of freight transported by mode m from I to j, both during t. The final step combines these twin functions into an estimate for Tijkmt.

A multiple-stage model developed by Hariton, Zohar, Le, and Lee (Ref 37) was unique in that it considered modal demands independently, and added functions to capture interdependent modal movements, such as intermodal transport. Meyer and Straszheim (Ref 38) used only a three-step forecasting process, with traffic generation, interzonal flow models (which include gravity models as well as linear programming formulations), and modal choice as the three stages.

Frederick Memmott (Ref 39) proposed a methodology for forecasting freight movement at the statewide level analogous to the four-step urban transportation planning process. The process involves four sequential stages — traffic generation, traffic distribution, modal split, and network assignment — and results in an assignment of freight traffic to network links. Memmott was able to use this method only under certain limiting assumptions. First, aggregate freight demand had to be service and price inelastic. Second, freight traffic generation was considered to be independent of the short-run modal split. Third, modal split was dependent upon modal attributes. Finally, freight demand forecasts had to depend strictly on economic activity.

Each of the models just described, with the exception of the Mathematica model, employed the gravity model as a major component in their frameworks. The gravity model assumes that flows between points are based on the "strength" of attractive forces between the two points and the significance of a friction factor. It is analogous to the law of gravitation in classical mechanics, which suggests that the gravitational force between two objects will increase as either object's mass increases or as the distance between the objects narrows. In freight transportation, the "mass" of an object could be considered the scale commodity of supply or demand at a node, with the friction factor representing modal attributes such as freight rates and transit time.

A freight-oriented gravity model for a given commodity might resemble the following:

$$T_{mij} = \alpha_0 P_i^{\alpha_1} P_j^{\alpha_2} Y_i^{\alpha_3} Y_j^{\alpha_4} M_i^{\alpha_5} M_j^{\alpha_6} N_{ij}^{\alpha_7} f_1(H) f_2(C) \tag{2.4}$$

$$f_1(H) = \left(H_{ij}^b\right)^{\beta_0} \left(H_{kij}{}^r\right)^{\beta_1} \tag{2.5}$$

$$f_2(C) = \left(C_{ij}^b\right)^{\gamma_0} \left(C_{kij}{}^r\right)^{\gamma_1} \tag{2.6}$$

where T_{mij} = tonnage of freight from origin i to destination j via mode m

P_l = population at location l

Y_l = income at location l

M_l = industrial character of location l

N_{ij} = number of modes available between i and j

C = cost characteristics

H = travel time characteristics

$\alpha, \beta, \gamma, b, r$ = coefficients to be econometrically estimated (equations from Ref 36)

The gravity model has been used independently of a multiple-stage framework as well. Tamin and Willumson (Ref 40) provide a recent example of a purely gravity-based freight forecast. Their gravity model was tested and calibrated for Bali, Indonesia, using maximum likelihood estimation and the nonlinear least squares method to determine appropriate coefficient values. But while the gravity model has proven to be moderately accurate as a predictive model in urban passenger transportation, its results in freight forecasting have been less successful (Ref 38). Moreover, the gravity model has little grounding in economic theory, fails to consider backhaul movements, requires considerable aggregation in commodity classification, and has very stringent data needs (Ref 22). If used at all, the gravity model is best suited for longer haul movements (Ref 38), or as a stage in a larger framework.

System-aggregate methods, while slightly more sophisticated, share some drawbacks with the single-stage aggregate methods discussed earlier. The gravity model has the potential to incorporate some of the effects of NAFTA as the "attractive" forces between markets across the border may be adjusted to reflect the impacts of the agreement. However, these adjustments will not be able to take into account the shifting of freight markets, as firms relocate production and distribution operations in accordance with maximizing profits under a different set of economic constraints. The system-aggregate methods are, in general, inflexible vis-`a-vis the structural changes NAFTA will impart upon the Texas-Mexico region.

Disaggregate Methods: The third type of econometric methods are disaggregate methods, which estimate modal choice at a "microscopic" level. These models require that freight data be analyzed at the individual decision unit of a single shipment. In that way, these methods strive to identify causality between certain modal and shipment attributes and the resulting modal choice.

There are two principal types of disaggregate methods: behavior models and inventory-theoretic methods. Behavioral models examine the freight modal choice decision from the perspective of the decisionmaker, commonly viewed as the shipper. Each shipper's modal choice decision is considered to be made independently according to commodity characteristics, shipper and production considerations, and modal attributes. These models hold that the decisionmaker's decision is based on maximizing the decisionmaker's utility function, which is a function of the attributes of the choice in relation to the preferences of the decision-maker. Because it is subjective, this utility is inherently nonmeasurable, as each utility measurement has a systematic component, which is both deterministic and observable, and a random component, which is stochastic:

$$u_{jn} = v_{jn} + \varepsilon_{jn} \tag{2.7}$$

where u_{jn} = utility of choice j for decisionmaker n

v_{jn} = observable utility of choice j for decisionmaker n

ε_{jn} = random unobservable utility component of choice j for decisionmaker n

Because of its stochastic element, random utility theory requires that choices be evaluated probabilistically. In other words, the probability that a decisionmaker n will select choice i is defined as:

$$P_n(i) = P\left(u_{in} \geq u_{jn}, \forall j \in C_n, j \neq i\right) \tag{2.8}$$

where $P_n(i)$ = the probability of choice i being selected by decisionmaker n

C_n = choice set for decisionmaker n

For binary choice analysis, three utility-based model forms are commonly used: probit, logit, and discriminant analysis. The probit model views the distribution of statistical disturbances as the sum of a large number of unobservable, independent components. This net distribution, according to the Central Limit Theorem, is distributed normally. The probability of selecting alternative I will be:

$$P_n(i) = \Phi\left(\frac{v_{in} - v_{jn}}{\sqrt{\sigma_i^2 + \sigma_j^2 - 2\sigma_{ij}}}\right) \tag{2.9}$$

where

$\Phi(\cdot)$ = standard normal cumulative distribution function,

σ_k^2 = the variance of the disturbance terms (ε_{kn}), and

σ_{ij} = the variance of the disturbance terms (ε_{in} and ε_{jn}).

The logit model assumes that the disturbance terms for each choice are identically and independently distributed according to a Gumbel distribution, which is very similar in shape to a standard normal distribution but is not symmetric. The probability that choice I will be selected is:

$$P_n(i) = \frac{1}{1 + e^{v_{jn} - v_{in}}} \tag{2.10}$$

Discriminant analysis seeks to partition a sample of modal choice observations into groups by mode based on the value of a linear combination of the explanatory variables. It assumes that all variables are distributed multivariate normal, and that the groups are homoscedastic with respect to the variables (i.e. the covariance is the same for both groups). For a pair of modal alternatives I and j, Zij is defined as follows:

$$Z_{ij} = \left[X - \frac{1}{2}\left(\overline{X}_i - \overline{X}_j\right)\right]^T \sigma^{-1}\left(\overline{X}_i - \overline{X}_j\right) + \ln\frac{Q_i}{Q_j} \tag{2.11}$$

where

X = vector of characteristics, and

Q_k = *a priori* modal share for mode *k*.

The probability of a mode being selected is:

$$P = \frac{e^{Z_{ij}}}{1 + e^{Z_{ij}}} \tag{2.12}$$

Hartwig and Linton (Ref 41) found all three model forms applicable in discerning the influence of transit time, freight rates, and transit time reliability on modal choice. Turner (Ref 42) focused on discriminant analysis in his study of modal selection in Canada.

Subsequent applications of behavioral models have shown considerable theoretical advancement. Winston (Ref 43) included the effect of uncertainty in modal attributes on modal choice. Daughety (Ref 44) noted that firms often diversify their transportation strategy in terms of mode or carrier selection as a response to risk, which is a reflection of the utility-maximizing behavior of purchasing managers.

The success of a behavioral model in forecasting modal choice resides in defining v_{jn} in such a way as to reduce the effect of ε_{jn}, such that the random element of decisionmaking exerts a minimal influence on modal choice. The influence of ε_{jn} cannot be fully eliminated since decisionmakers lack both perfect information and the ability to perceive information perfectly. To the extent that the appropriate data is available, however, the capability of behavioral models is limited only by the imagination of the analyst. As such, it would be an excellent candidate for forecasting how firms respond to the effects of NAFTA in their modal choice decisions. Behavioral models suffer in that estimates for model coefficients are based on a static observation of dynamic decisionmaker behavior. In comparison to the earlier stated econometric models, however, behavioral models enable modal choice forecasts to be more responsive to individual firms and industries, as well as to changes in infrastructure characteristics and attributes of commodity demand.

The inventory-theoretic approach is a special type of disaggregate method which places the modal choice decision in the context of a firm's logistics strategy. Instead of solely minimizing transportation costs, shippers act to minimize logistics costs, considering inventory as well as transport costs. Inventory-theoretic models, initially formulated by Baumol and Vinod (Ref 45), assume that firms act to maximize short-run profit. More general models of this type have included all of a firm's costs into consideration of modal choice, and have considered modal choice as part of a joint choice process; Chiang (Ref 46) and McFadden, Winston and Buersch-Supan (Ref 47) are examples of this. These models consider the modal choice decision to be correlated with the selection of a shipment size, and are limited only in the ability of the analyst to model the firm's inventory management system.

Disaggregate methods offer several advantages over other econometric specifications. First, disaggregate models can be specified to be well-grounded in behavioral or economic theory, and may consequently offer an excellent representation of the institutional realities of freight modal choice decisions. In addition, disaggregate methods allow for richer econometric specifications than aggregate or system-aggregate methods, permitting decision-maker characteristics to be included as a consideration in the decision process. Finally, because they may incorporate specific commodity and decisionmaker characteristics, disaggregate models allow for more precise estimates of market elasticities with respect to modal characteristics (Refs 24, 43). All of these characteristics allow the model to be more responsive to factors which influence production and modal choice decisions. For this reason, disaggregate methods present an attractive means of forecasting freight demand.

The primary flaw associated with disaggregate methods is the stringency of their data requirements. Disaggregate models require a large number of individual shipment observations for calibration. Each observation must specify all shipment and modal characteristics which are deemed relevant to modal choice. Such observations may be difficult to obtain because of firms' interests in safeguarding the confidentiality of their production and distribution decisions. In shipments across the border, the complexity of documentation involved in international freight makes data collection difficult.

For this reason, most disaggregate models have been calibrated with narrowly defined data sets. Calibration data has generally been confined to a single carrier, a single commodity, a small set of origin-destination pairs, or data which predates publication by several years. Developing a model capable of accurately forecasting freight demand between Texas and Mexico will require current data from a variety of carriers and industries over the entire region. If data needs can be met at a reasonable cost, then a disaggregate method would represent an excellent approach to forecasting the effects of NAFTA on freight transportation at the Texas-Mexico border.

2.4.2 Network Methods

A second broad class of freight forecasting methods includes network-based freight demand models. These models apply an optimization rule to an objective function, governed by a system of equations with an appropriate set of data, in order to predict the distribution of freight traffic at some point in the future. In general, the optimization rule requires that all system users behave and interact in such a way as to minimize system costs; this is known as Wardrop's second principle (Ref 48). Network models revolve around linear programming (LP) formulations, which minimize transportation costs subject to production and transportation capacity restraints. This section considers two types of network optimizations: spatial price equilibrium models and freight network models.

Spatial Price Equilibrium Models: The spatial price equilibrium model (SPEM) was created by Samuelson (Ref 49) as a market-based approach to modeling freight based on economic balance in the freight market. In SPEM, the economy is defined by a network of nodes, each with an elastic commodity supply and demand between nodes based on the relationship between the cost of transportation and the price differential of commodities between nodes. If the price differential exceeds the cost of transportation, then commodities will flow from the lower price node to the higher price node. Otherwise, there is no market-based incentives for commodities to move; hence, there would be no freight movement.

At the spatial price equilibrium, the price differential between nodes equals the cost of transportation between nodes. To reach this equilibrium, SPEM applies LP techniques to determine the node-level volume of export and import traffic for each commodity. It simultaneously determines interregional flow, level of regional production, consumption, and market prices. The equilibrium is defined as follows:

$$\Pi_i^k + c_{ij}^k \geq p_j^k \quad \text{if } x_{ij}^k = 0 \tag{2.13}$$

and

$$\Pi_i^k + c_{ij}^k = p_j^k \quad \text{if } x_{ij}^k > 0 \tag{2.14}$$

subject to:

$$\sum_j x_{ij}^k = O_i^k, \quad \sum_i x_{ij}^k = d_j^k \quad \text{for all } i, k \tag{2.15}$$

$$x_{ij}^k \geq 0 \quad \forall i, j, k \tag{2.16}$$

$$\Pi_i^k = S_i^k\left(O_i^k\right) \quad \forall i, k \tag{2.17}$$

$$p_j^k = D_j^k\left(d_j^k\right) \quad \forall j, k \tag{2.18}$$

where

O_i^k = the amount of commodity k produced at origin i,

d_j^k = the amount of commodity k demanded at destination j,

x_{ij}^k = interregional flow of commodity k between i and j,

Π_i^k = the supply price of commodity k at origin i,

c_{ij}^k = transportation cost for commodity k between i and j,

p_j^k = the demand price for commodity k at destination j,

$S_i^k(\cdot)$ = the inverse supply function for commodity k at i, *and*

$D_j^k(\cdot)$ = the inverse demand function for commodity k at j.

This framework allows SPEM to explicitly consider the economic decision involved in freight transportation. Most econometric methods described earlier, with the exception of the gravity model, presume that a freight movement will happen; in other words, they are conditional on the decision to move freight in the first place. SPEM proceeds beyond this by acknowledging that a shipment will occur only when it is profitable. In this way, it integrates transportation decisions into production decisions, similar to the inventory-theoretic methods. NAFTA's implementation is likely to reduce the real cost of transportation, which would introduce new competitiveness for suppliers of factors of production. SPEM appears capable of representing this in its framework.

SPEM has several disadvantages, however. First, the model is most properly applied at a very disaggregate level with respect to commodities, such that each commodity within a commodity class is mutually and (nearly) perfectly substitutable with the other entries in that class. That is why the same commodity may not have positive cross-flows for a given *i-j* pair; i.e. $x_{ij}, x_{ji} > 0$. For example, American-manufactured automobiles are sold in Europe, while European autos are sold in the United States. While both commodities can be classified as automobiles, they are not perfectly substitutable; hence, this situation could be a spatial price equilibrium only if these are classified into separate commodities. Shipments of homogeneous commodities, such as milk, would not have positive cross-flows, and can hence be aggregated into one commodity group. The existence of such homogeneity is rare, however, and a fully-specified SPEM for the Texas-Mexico region might require thousands of commodities.

Second, SPEM employs a system-optimizing framework, which may not be representative of actual market behavior. Shippers and carriers will, generally, not behave collectively in order to maximize system performance. The equilibrium solution proposed by SPEM will depict the set of flows which is perhaps most efficient for the system, but this may not represent the flows that actually occur. Economies of scale in both transportation and production may be realized in SPEM when they cannot be achieved by firms acting independently.

A final disadvantage of SPEM is it requires that transportation costs be constant regardless of the quantity of flow. Relaxing this assumption would make the solution to the problem more applicable to the actual freight market, but also mathematically intractable. Except in the simplest cases of demand for and pricing of transportation services, these models are inadequate to address the complexities of the freight transport market (Ref 48). For this reason, it appears that SPEM would be incapable of accurately forecasting the effects of NAFTA on freight transportation between Texas and Mexico.

Freight Network Models: Freight network models strive to identify a market equilibrium between shippers and carriers where shippers are the source of freight demand and carriers determine the transportation supply. These models assign freight tonnage on a transportation network according to the attributes of the network's nodes, such as factories or retail outlets, and links, such as rail lines and highways. The first such model was developed by Roberts in 1966 and was subsequently extended by Kresge and Roberts in 1971 for application to the Colombian transport network. This multiple-stage model, known as the Harvard-Brookings model, analyzes transportation system performance at the route level for a multimodal, multicommodity network. After defining the transportation network and calculating regional supply, demand, and production costs for each commodity, the model assigns modal flows at the commodity level, according to the characteristics of each network link and commodity. The Harvard-Brookings model has no feedback process, which implicitly assumes that modal choice is made independently of mode performance (Ref 50).

Several other predictive freight network models were developed in the late 70s and 80s. Some of these are described in Table 2.8. Of particular note is the Pennsylvania-Argonne class of models, also known as freight network equilibrium models (FNEM). FNEM consists of a multiple-stage process in which shippers are assumed to act user-optimally (akin to Wardrop's first principle) while carriers act in a system-optimal manner. Model inputs include production and consumption amounts and a specified demand function. The shippers' submodel converts these into a user-optimized, elastic demand, aggregate network. A decomposition algorithm constructs O-D paths in order to generate O-D patterns by carrier. The carriers' submodel — the third step — results in a system-optimal, fixed demand, detailed network, which will produce arc flows, arc costs, path flows, and path costs (Ref 48).

Table 2.8 Characteristics of major freight predictive network models (Ref 58)

Criteria	**Harvard-Brookings**	**CACI**	**Lansdowne**	**Princeton**	**Penn-Argonne**
Multiple modes	Yes	Yes	No	No	Yes
Multiple commodities	Yes	Yes	Yes	Yes	Yes
Sequential/simultaneous loading of commodities	Both	Sequential	Sequential	Sequential	Both
Congestion effects	No	Yes	No	No	Yes
Elastic transportation demand	Yes	No	No	No	Yes
Explicit treatment of shippers/carriers	Shippers	Shippers	Both	Both	Both
Sequential shipper and carrier submodels	NA	NA	Yes	Yes	Yes
Simultaneous shipper and carrier submodels	NA	NA	No	No	No
Sequential/simultaneous macroeconomic and network models	Sequential	Sequential	Sequential	Sequential	Sequential
Nonmonotonic functions	No	No	No	No	Yes
Explicit backhauling	No	No	No	No	No

References: "Harvard-Brookings" (Ref 51), "CACI" (Ref 52), "Lansdowne" (Ref 53), "Princeton" (Ref 54), and "Penn-ANL" (Ref 55).

Recent years have seen STAN, a multimode, multicommodity package developed at Montréal University, gain acceptance as a planning tool for freight transportation. It is used to compare different forecasts for demand between origins and destinations or infrastructure improvement alternatives against a set of commodities and transportation alternatives (Ref 56).

Of the modeling tools discussed so far, freight network models are among the most powerful, for they can be used to estimate freight demand for specific corridors, and even modal links. Freight network models are also different in that they explicitly consider attributes of the supply of transportation services, allowing link capacity to play a role in the routing of shipments. As these models have developed over time, predictive capability has improved considerably, and STAN is now commonly used for medium-range to long-range planning in Europe (Refs 48, 56).

Freight network models would face an unusual handicap in applications to international markets, however, because they would require a large amount of detailed information regarding the infrastructure in the border region, such as delay costs associated with each border crossing and intermodal facility. As the complexity of the border transportation system increases through the provision of more intermodal freight options, freight network models may become more difficult to apply. As these models continue to improve, however, this may not be a significant issue, provided that the appropriate data can be obtained. STAN is already improving in this regard, as it has the capability of including most intermodal combinations and has been applied to international analysis within Europe (Refs 56, 57).

Data collection is also a concern when it comes to specifying and identifying commodities. Like SPEM, freight network models improve in predictive accuracy as commodity groups become more disaggregate. Commodity groups must be sufficiently disaggregate in order to be individually homogeneous enough to allow for cross-flows and to capture backhaul effects (Ref 58). However, the cost of application will increase as the number of commodity groups grows.

Freight network models rely on optimization rules to determine network flows. While it seems reasonable that shippers and carriers will act to optimize their interests, it may be difficult to quantify the factors which govern this optimization. For example, a firm's inventory policy may dictate smaller and more frequent shipments as a way to lower inventory costs. However, unless shippers' optimization models are constructed to consider inventory costs, the network model will tend to overestimate the average shipment size and underestimate the number of vehicles moving for a given commodity flow. Noncost considerations (e.g., reputation for dependability, shipment safety, and modal flexibility) undoubtedly influence modal choice, but these factors would also be difficult to quantify in an optimization framework. Newer versions of freight network models will likely seek to address these issues, such that predictive accuracy will continue to improve.

A more pressing concern in applying network models to analyze the effects of NAFTA is whether they can be effective in developing planning forecasts in an economically dynamic region. One significant effect of NAFTA is that firms' transportation costs will make up a smaller share of production costs. Accordingly, decisions regarding target markets and locations of facilities may change. Freight network models rely on exogenously derived origin-destination patterns for commodity demand, and generally lack a feedback process to adjust trade flows according to transportation costs. Current network models are not responsive enough to changes in economic conditions to be able to reflect the structural change that would occur in a broad trade agreement. Therefore, if a freight network model were to be used to forecast the transportation impacts of an economic catalyst like NAFTA, it must be used iteratively with an economic model, such that changes in the spatial distribution of productive capacity can be represented.

2.5 SUMMARY

Trade between the United States and Mexico has increased in recent years, and the passage of the North American Free Trade Agreement portends more economic interaction between the two nations. Given that the infrastructure in the border region requires reconditioning and expansion, there is a clear need for forecasts to assess the transportation impacts of NAFTA.

The three efforts to forecast freight transportation between Texas and Mexico (identified and discussed in this chapter) have failed to adequately address the structural effects that NAFTA will impose on the economic interrelationship between the two regions. A review of the freight demand forecasting literature found an array of methods which, while having analytical strengths, still cannot satisfactorily incorporate economic dynamics into the development of transportation forecasts. In light of this theoretical background, and given the need for freight forecasts for the Texas-Mexico border region, the next chapter presents an alternative methodology for forecasting freight demand that addresses the issues raised in this chapter.

CHAPTER 3. METHODOLOGY DEVELOPMENT

Several forecasts have predicted the impacts of the North American Free Trade Agreement (NAFTA) on freight transportation crossing the Texas-Mexico border. These forecasts fail to consider at least two factors which significantly affect the volume and modal assignment of traffic across the border. First, these forecasts fail to address the effects of the border itself on transportation and trade. Second, these forecasts are insensitive to the dynamic effects of NAFTA and industrial innovation on the economic relationship between the United States and Mexico; therefore, future patterns of goods movement may share little resemblance with current patterns. These factors call for a different approach to be used to forecast freight modal demand across the border.

This chapter introduces a freight forecasting methodology which accounts for the above factors. The first step in developing this methodology is to frame the problem by defining a methodological objective. This is followed by an assessment of the issues which are specific to a planning-oriented forecast of the demand for freight transportation across the border. In order to reflect the changes in economic structure that NAFTA would cause, the methodology is oriented to mesh with the hierarchy of decisions that a firm will make regarding production and modal choice. This hierarchy of decisions is discussed, followed by an outline of the methodology itself, which is developed in the remainder of this report.

3.1 PROBLEM STATEMENT

This section defines the forecasting problem which is being analyzed, in terms of its objective, its system definition, its intended results, the precision of these results, and its forecast horizon.

Objective: The objective of the methodology developed in this report is to generate forecasts for freight transportation flows across the Texas-Mexico border. These forecasts must be responsive to the full array of factors which may influence firms in their production and modal choice decisions. This objective results from the needs of planning-oriented efforts associated with the implementation of NAFTA. The economic environment in which firms make business decisions, including modal choice decisions, has already been dramatically altered by NAFTA. For this reason, a methodology developed in this setting must reflect those factors which influence modal choice at the firm level.

System Definition: The ability of the methodology to accurately forecast cross-border freight traffic depends on how the system is defined. This problem requires that the system be defined in terms of identifying which regions are considered to be a part of the economic system and which patterns of freight movement should be included in the modeling process.

Geographically, the system should be defined such that it exhibits a high degree of economic self-sufficiency, with flows entering and leaving the system comprising a small portion of the system's total economic activity (Ref 59). This will enable the methodology to isolate those factors which are most influential in determining the distribution and modal selection of transborder freight movements. This definition causes the system to embrace existing high-volume trade flows entirely within the system. In Mexico, these corridors correspond primarily to transportation links which run parallel to the mountain ranges; in Texas, these flows extend to the east from Houston, and to the north and northeast from Dallas (Ref 60). It is likely that these trade flows will continue to represent the bulk of freight activity across the border, because they have resulted from concentrations of factors of production in relation to the provision of transportation infrastructure.

To sharpen the focus on trade crossing the Texas border, one would prefer to limit the system to include only Mexico and Texas. However, it may difficult to isolate this region's economy in order to get appropriate data, since many southbound shipments destined for Mexico do not originate in Texas, and many northbound shipments originating in Mexico will not terminate in Texas. Texas' economy is more interdependent with the economy of the United States as a whole than with Mexico. Therefore, one should define the system to include freight flows within or between Mexico and the contiguous United States. This allows the forecast to encompass the range of options firms may have in spatially re-allocating productive capacity in response to NAFTA.

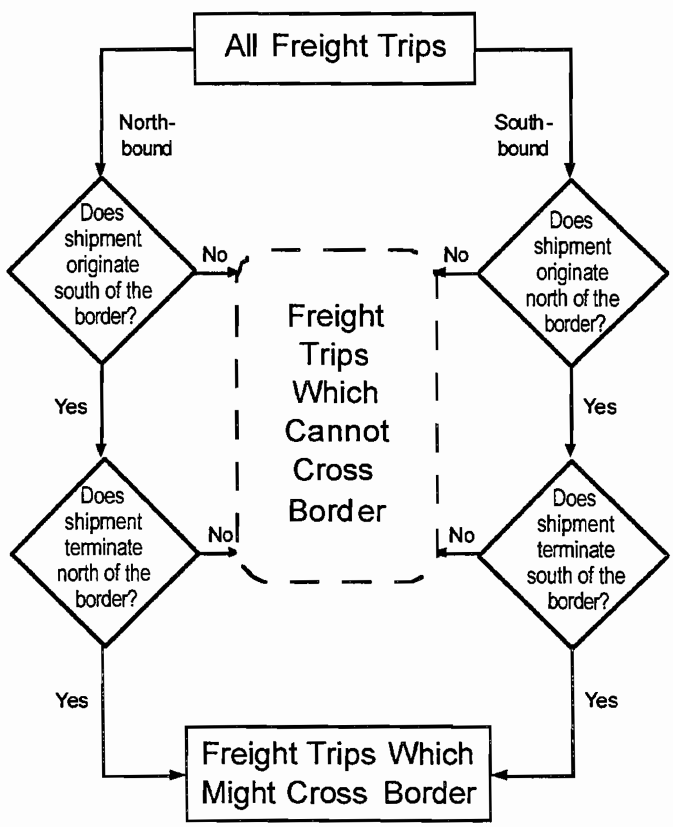


Figure 3.1 Identifying potential border crossing trips

By limiting the system to consider only the freight trips between the United States and Mexico, not all transborder trips will be included, as is shown in Figure 3.1. Trips across the U.S.-Mexico border are a subset of all freight trips, which reflect interregional relationships throughout the economy. However, the proportion of transborder trips outside of the U.S.-Mexico system will be small. The border is commonly viewed by carriers as an inconvenience, owing to border clearance inspections, queuing for motor carriers at bridges, and equipment or crew switching at the border; shippers generally must make a conscious decision to cross the land border. As shipment distance increases, railroad and motor carriers, which are required to use the land border, would have competition from other modes. Table 3.1 accordingly assesses the likelihood of a border crossing occurring for shipments between regions within North and South America. Such pass-through traffic constitutes a small component — at most, 1 percent — of freight traffic across the border overall.

Results: The output of this methodology is to assist in planning efforts at the border to determine both infrastructure requirements and inspection and processing needs. The NAFTA forecasts in Chapter 2, while varying in estimates, agreed that trade between Texas and Mexico will continue to increase, compounding stress on the highway system and border infrastructure. This methodology should therefore strive to assist planners in addressing the problems that will accompany increased trade by providing estimates of vehicle traffic volume by mode.

Table 3.1 Likelihood of using border crossing by origin-destination pair

	Destination			
Origin	**Canada**	**U.S.**	**Mexico**	**S. of Mexico**
Canada	Very doubtful	Very doubtful	Possible	Doubtful
U.S.	Very doubtful	Doubtful	Very likely	Possible
Mexico	Possible	Very likely	Doubtful	Very doubtful
South of Mexico	Doubtful	Possible	Very doubtful	Very doubtful

Precision of Results: Ideally, the methodology would be able to assign the impacts of NAFTA-related traffic to individual bridges and crossings. To generate forecasts of such detail would require a very large amount of quantitative data regarding the transportation network, link conditions, and shipment routing, such as would be needed to implement a freight network model. Such detail is impractical for a system which is defined to include the entirety of the United States and Mexico. This methodology assumes that modal choice for a border crossing freight movement is largely determined according to shipment characteristics and origin location, not as the result of an explicit shortest-path algorithm between the origin and destination. Therefore, the methodology seeks to forecast the volume of shipments which will cross the entire Texas-Mexico border, rather than to predict traffic volumes at specific bridges and crossings.

Forecast Horizon: The selection of an appropriate forecast horizon, or the length of time between when the forecast is made and the forecast year, involves several trade-offs. A longer horizon will be more useful in transportation planning, but it introduces greater uncertainty into the forecasts. The analyst is forced to consider the forecast's sensitivity to macroeconomic conditions, major changes in the transportation infrastructure, significant mobility of factors of production, and other factors. A shorter forecast horizon, while reducing the forecast's utility for planning purposes, may allow the analyst to treat certain elements of the problem as negligible, especially those relating to long-run decisions, simplifying calculations and improving the confidence interval of any generated forecasts. Because this methodology is directed toward transportation planning, this methodology must generate long-run forecasts, with a forecast horizon of approximately 20 years, in order to effectively and efficiently allocate border investment.

3.2 ISSUES

Freight forecasts have often been formulated for socioeconomically uniform regions during times of relative economic stability. Forecasting freight demand across the Texas-Mexico border under NAFTA, on the other hand, involves recognition of the numerous differences between the United States and Mexico and the likely effects of NAFTA on reshaping production and shipping patterns. This section elucidates the complications and consequences of these issues, highlighting their relevance to forecasting freight demand between Texas and Mexico.

3.2.1 International Border

The first issue of consequence in developing this forecast is the presence of an international border within the system. The Texas-Mexico border separates significant differences in industrial structure, economic welfare, stability of governmental and political institutions, infrastructure quality, culture for conducting business, and other factors. The act of merely crossing the border — north or south bound — complicates the transportation of goods significantly, due to documentation requirements and processing delays. This methodology must explicitly address both facets of the border issue: the marked differences between the two nations within the system, as well as the effects of the border on freight movement.

Of the differences between the two nations, the exchange rate is perhaps the most unstable and critical element. While the U.S. dollar has enjoyed general stability on world financial markets, the Mexican peso has fluctuated wildly. These fluctuations in the value of the peso have caused the balance of trade between the two nations to shift dramatically over the past fifteen years. In fact, the most recent devaluation of the peso in late 1994 and 1995 caused a U.S. trade surplus to be transformed into a deficit, as the devaluation increased the price of American products relative to that of Mexican goods. It is important to note, however, that the exchange rate will also affect intermediate goods used as inputs to other industries. Mexico's maquiladora industry has historically thrived whenever real Mexican wages are depressed as a result of a "weak" peso, as firms set up new plants to take advantage of lower factor prices. The methodology must be sensitive to the trade effects resulting from changes in the exchange rate.

Other differences between the regions complicate this methodology. Infrastructure quality differs considerably across the border according to modal attributes, such as transit speed, safety, and accessibility. Therefore, the methodology must recognize that a modal transfer may occur near the border region. Methods of production also differ between the two nations, as Mexican production is generally more labor-intensive than United States production. If NAFTA causes some firms to move across the border to take advantage of different cost structures, it is likely that their supply needs will also change. A plant moving to the United States might have a greater need for replacement capital parts than a Mexican plant might, for example. Governmental structures and statutes enjoy a greater degree of stability and enforcement in the United States than in Mexico. Consequently, the methodology must be sensitive to the effects of political instability on trade. With the many substantial differences that exist between the two countries, the methodology must be able to distinguish Mexico and the United States as distinct entities while still recognizing their economic relationship as one system.

The border interface, due to processing and intermodal transfers, is another issue which must be addressed in the methodology. As was discussed in section 2.2, shippers and carriers consider border clearance procedures to be an inconvenience to efficient freight movements. The implementation of NAFTA, combined with the introduction of "electronic border crossings" should make the border crossing more efficient by easing congestion at the bridges. Electronic border crossings are a form of Intelligent Transportation Systems (ITS) which use wireless communications and customized computer software to preclear commercial vehicles through customs and immigration procedures for both the United States and Mexico. This system was demonstrated at Otay Mesa in San Diego in late 1995, and is expected to gain widespread implementation across the border (Ref 61). Because crossing the border will become less costly to shippers, firms may be more apt to distribute new capacity on either side of the border, in order to take advantage of differences in factor prices. Nevertheless, the presence of a border crossing may still influence modal choice decisions, and must be considered in the methodology.

3.2.2 NAFTA Implementation

The second significant issue which must be addressed is the effect of full implementation of the North American Free Trade Agreement on trade between the two economies. The removal of tariffs and trade barriers between Mexico and the United States will reduce the final price of imported goods in each nation, increasing the purchasing power of consumers, leading to an increased demand for certain commodities. As the mix of goods moving between the nations changes, so will transportation needs change. The methodology must reflect the effects that reduced prices will have on market size for the Texas and Mexico economies.

NAFTA will not only increase the trade volume between the two nations, but it will also change where economic activities occur and how these activities relate to each other and to their markets. NAFTA represents a long-term change in the economic relationship among North American nations; consequently, one would expect to see significant changes in capital investment patterns as NAFTA takes root. In particular, the disparity in wages and education levels between the United States and Mexico provides an opportunity for firms to use the comparative advantages of each nation's work force to reduce production costs. This may lead to an increase in maquiladora activity in central Mexico, where there is a more educated and stable labor force. Consequently, maquilas may be able to expand their usefulness into other industries, creating an increase in transborder trade. The methodology must be able to reflect such structural changes that have resulted and will continue to occur as a result of NAFTA.

As described in section 2.2.3, NAFTA also provides for the liberalization of operating practices for transportation companies between the two nations. Carriers now have much greater freedom to operate between nations without the necessity of partnerships and complex managerial arrangements. In anticipation of NAFTA, many U.S. carriers formed and expanded partnership agreements with Mexican counterparts, in order to make transborder freight movements "seamless." As the border becomes more seamless still, the nature of the freight market may change. For example, intermodal and rail shipments, which are more economical with longer-haul segments, may become accessible to more freight markets, perhaps reducing the need for expansion of bridge crossings. Carriers have already shown significant innovation in intermodal movement over the past decade, and this innovation may further affect the level and quality of service offered by different modal choices. The methodology must be responsive to these market changes.

Because trade between Texas and Mexico is dominated by intermediate and finished manufactured goods, the impact of technological change on trade forecasts could also be substantial. This technological change will be manifested in both the emergence of new industries and in the evolution of production techniques. The speed, degree, type, and direction of technological change will affect the economic structure of the system more than any other factor, with the exception of the exchange rate. Like the exchange rate, the impact of technological change is difficult to forecast, especially over a longer forecast horizon. It is therefore critical that the freight forecasting methodology be sensitive both to the static effects of new technologies and goods on producer and consumer behavior, as well as to the dynamic effects of technological change on investment decisions by manufacturers.

3.2.3 Synopsis

This discussion indicates that a properly developed methodology for forecasting freight movement between Texas and Mexico resulting from NAFTA must explicitly consider the economic relationship between the two nations, as well as the climate it creates for decisions in individual industries. Moreover, the dynamics of this relationship require that the methodology be sensitive to numerous factors, specifically the exchange rate and the structural effects of NAFTA implementation.

3.3 DECISION HIERARCHY FOR FIRMS

A distribution of freight flows is simply the sum of decisions made by individual shippers. Accordingly, it makes sense for a freight forecasting methodology to attempt to replicate the order and hierarchy in which firms make modal choice decisions.

Firms are confronted with several decision levels with varying time frames: long-run (5 to 20 years), intermediate-run (6 months to 10 years), and short-run decisions (up to 1 year), as shown in Figure 3.2. Chiang (Ref 46) and Abdelwahab and Sargious (Ref 62) separated firm-level decisions in such a way. These time frames correspond to the amount of time in which a decision will constrain the firm's operational plans. The time frames overlap in order to account for differences between industries and regions. This section describes each of these decision levels in detail.

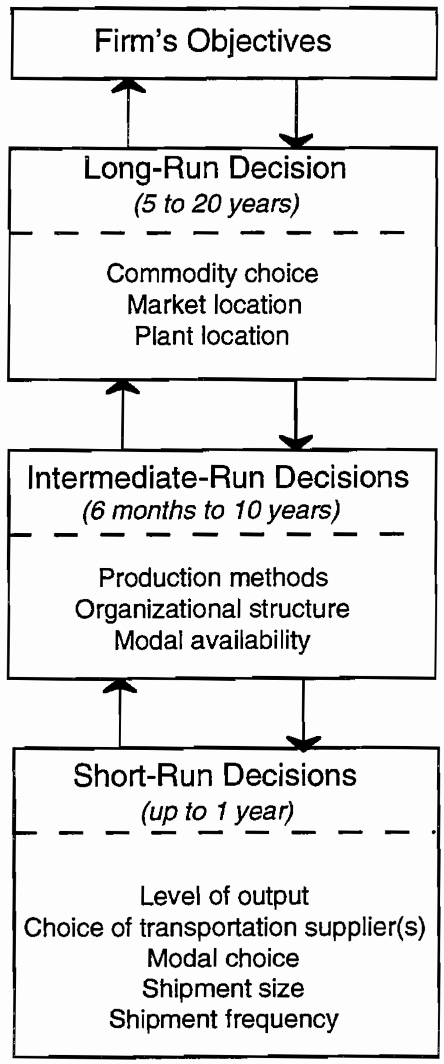


Figure 3.2 Decision hierarchy for firms

3.3.1 Long-Run Decisions

Long-run decisions correspond to the most fundamental decisions a firm will face, such as commodity or product choice, market location, and plant location. These generally have a planning horizon of between 5 and 20 years, involve significant sunk costs, and provide a foundation upon which other choices are made.

The most elementary decision a firm makes is to determine the commodities to be sold and the markets to be entered. The firm must initially identify industries and geographical regions for which sufficient product demand exists to suggest the strong probability of an acceptable rate of return on capital. The choice of industry will require investment in the appropriate capital equipment for production and inventory, which will involve a considerable fixed cost to the firm. Entry into new markets may pose another significant sunk cost to a firm, as it involves significant fixed promotion and distribution costs. The degree of sunk costs for entry into new markets depends upon the industry. For some industries, sunk costs are small enough that market entry and exit becomes more of a short-run decision.

The plant's location will be dependent upon the markets which are to be served, since transportation costs may comprise a significant portion of the firm's production costs. For a manufacturer, plant location will be selected as a function of many competing factors, including land costs, tax incentives, labor supply, location relative to factor inputs, and degree of transportation access. In a state of spatial equilibrium, any savings in land costs associated with a specific location will result in greater costs for other factors. A factory located in the periphery of a city will likely have lower land costs than a location near the city center. However, the peripheral location may require higher transportation costs for goods movement such that, in equilibrium, the costs between locations should be comparable. Similarly, a firm may locate a maquiladora near a U.S. port of entry and hence reduce transportation costs, or farther away from a border city in order to enjoy lower land costs.

3.3.2 Intermediate-Run Decisions

Once a firm has selected a commodity to produce and has identified market and plant locations, the firm must create an internal operational structure to produce and distribute its output. This is done through intermediate-run decisions, such as selecting a method of production, defining an organizational structure, and determining the availability of modal options. These decisions take all long-run decisions as fixed and have a forecast horizon of between 6 months and 10 years. Their smaller planning horizon means that intermediate-run decisions also involve smaller sunk costs than long-run decisions do.

The firm may select one of a variety of production methods, according to the mix of capital and labor employed. Excluding the use of rental equipment and temporary laborers, there is some inertia with the selection of an appropriate production method. However, not all capital investments at the plant level may be long-run in nature, and the firm may use this flexibility to minimize production costs. If interest rates were to jump suddenly, making capital more expensive, firms might opt to choose more labor-intensive production methods. Similarly, if wage rates were to rise, firms would seek greater degrees of automation and capital utilization in their production processes to reduce production costs. By changing production methods, a firm can reduce its costs without changing its plant location.

Firms must also establish an organizational structure by which production and modal choice decisions will be made. This structure includes a hierarchy of levels of authority within the firm, and a vehicle by which decisions will be made. Regarding modal choice, the type of organizational structure will provide answers to several questions. How much decisionmaking authority is delegated to plant managers? Is modal choice decided at the plant level or on a companywide basis? Does the firm operate its own logistics strategy or does it choose to subcontract it? The firm's organizational structure will establish how modal choice decisions are made, and will play a role in the degree of rate concessions a shipper may receive due to freight volume (Ref 63). The "planning horizon" for this type of decision depends on the size of firm under consideration, as it will be disproportionately more costly for larger firms to change their organizational structure than smaller firms.

The availability of modal options is sometimes established as a conscious decision by the firm, often in conjunction with a plant location decision. For example, if a firm desires to have convenient access to maritime transport, it would likely locate its operations near a port or on an inland waterway. Firms seeking rail access would position themselves in proximity to existing railroad lines. If the firm specializes in a commodity that is best transported by motor carriers, the firm will locate its plants near major highways. However, a firm may still change its modal options even after its plant locations are fixed. The firm may decide to add a rail siding after a plant is in place in order to expand its service market. If the firm already has multiple modal options available, it may choose to introduce special handling or packaging equipment to improve the cost-effectiveness of using one mode over another. The time horizons involved in establishing which modal options are available to a firm vary depending on the mode in consideration, according to the level of associated sunk costs. For example, it would be a long-run decision for an inland firm to establish maritime as a reasonable modal alternative, as it would require the burrowing of a canal. For motor carrier movements, the sunk costs are much lower, since trucks do not operate on a fixed guideway and can be called to service a specific location at relatively short notice. This decision is generally made after considerations are given to plant and market location, but because it still limits a firm's transportation options, it is considered an intermediate decision.

3.3.3 Short-Run Decisions

Short-run decisions are those decisions with a time horizon of less than one year. Given a commodity, plant and market locations, a set of production technologies, an organizational structure for decisionmaking, and a set of available modal options, the firm still has some operational flexibility. This flexibility is exercised in short-run decisions, where the firm must choose a level of output, supplier(s) of transportation services, the transportation alternative that will be selected, shipment size, and shipment frequency.

The level of output is, next to the choice of commodity type, the most fundamental decision in production. Selecting an output level is a short-run decision only to the extent that the production activity is a short-run process. This decision will be constrained by market conditions and equipment restrictions: a firm would not produce more output than could be sold, and it cannot exceed the productive capacity of its plant's technology. Once a production technology has been put in place, the firm has the option of utilizing as much or as little of the technology's capacity as it chooses. This flexibility allows the firm to make short-run adjustments in its output in order to meet product demand in a profit-maximizing manner.

Firms also must make a decision regarding the supplier of transportation services. A firm may opt to act as its own carrier, renting or purchasing equipment and hiring personnel to manage their own freight operations. Smaller firms will more frequently join into a contract with either a freight forwarder or a carrier to provide transportation services. The use of contracted transportation services means that, for some firms, supplier choice may be more of an intermediate-run decision than it is for other firms. Nevertheless, in the absence of contractual requirements, supplier choice would clearly be a short-run decision, based on production requirements and supplier prices.

In general, modal choice is a short-run decision, as it can be adjusted for individual shipments at the discretion of the shipper. Again, however, if the firm contracts out its transportation needs, it may not be able to make a decision regarding modal choice in the short-run. Contractual obligations may similarly inhibit the ability of a firm to establish an average shipment size. The shipment size may be doubly bounded based on the transportation alternative selected: an upper bound due to the capacity of the selected alternative, and a lower bound due to minimum shipment size requirements that a carrier may have. It also may be constrained by a firm's inventory capacity in relation to its production batch size. Ordering frequency will be the quotient of level of output and the mean shipment size. Contractual obligations may also stipulate minimum frequency requirements, which would put limits on shipment size. This interaction between modal choice and optimal shipment size has been the impetus for some joint choice decision models, such as Chiang, Roberts, and Ben-Akiva (Ref 64). These models are a reflection that these decisions share a common planning horizon.

3.3.4 Decision Interactions

According to Figure 3.2, a short-run decision, such as modal choice, is made after making all decisions of longer time horizons. At each decision level, the firm makes choices that will optimize its objective function. Therefore, while modal choice is in itself a short-run decision, it is important to understand how that decision interacts with other decisions facing a firm.

Stock and LaLonde (Ref 65) and Brand and Grabner (Ref 63) proposed that the modal choice decision can be viewed as the result of a four-stage process involving problem recognition, an information search process, a choice process, and post-choice evaluation. First, the firm recognizes a problem by acknowledging its need to improve its transportation services. Next, the firm commences a process of gathering information about available alternatives. The firm then weighs the alternatives in a choice process, making a choice in response to its objectives. Finally, the firm conducts a post-choice evaluation, which could include an analysis of several performance measures (e.g., service reliability, customer complaints, claims and loss experience, shipment tracing, and distribution cost audits). These performance measures are compared to the firm's objectives, with a failure of the chosen transportation strategy to meet the firm's objectives initiating a new search process.

Suppose a firm is relying strictly on motor carriers to meet all of its shipping requirements, due to its surrounding infrastructure. After some evaluation, the firm finds that its market-share objectives are not being satisfied. The firm examines all possible motor carrier alternatives and finds that none of them will cause the firm to realize its market share objective. Consequently, the firm will consider intermediate-run solutions, such as constructing a rail spur to connect the firm to the local rail network, which will increase the number of short-run options available to the firm. If none of these short-run alternatives allows the firm to meet its objectives, it may consider more drastic, permanent solutions, such as relocation or the construction of a new plant, creation of new products, or a change in the target markets. Finally, if even these solutions prove ineffective in attaining the firm's goals, the firm will be required to change its objectives. This may happen in a depressed economy where the firm has an overly generous expectation of the desired economic rate of return on a productive investment. Figure 3.2 reflects this four-step process by indicating that interactions between decision levels proceed both downward and upward.

3.4 METHODOLOGY STRUCTURE

The preceding discussion demonstrated that the modal choice decision cannot be considered independently, and that they must take into account other decisions that firms make as well as the environment in which these decisions are made. The decision hierarchy, therefore, plays a critical role in forecasting the effects of NAFTA because the trade agreement alters the long-run economic environment in which firms operate. Any intermediate-run and short-run decisions which firms made prior to NAFTA may no longer be optimal. Consequently, one would expect to see substantial changes in firm behavior as a result of NAFTA, and the methodology must be able to reflect that.

This firm-level decisionmaking process may be considered as a framework for a system-wide freight forecasting methodology. This would require an assessment of the region's economic structure, followed by an understanding of firms' operational responses to this structure. Their operational response would consist of short-run decisions regarding modal choice and shipment size. These decisions, of course, are made in the context of earlier decisions regarding organizational structure, production methods, and the availability of modal options. Figure 3.3 suggests, accordingly, that there are three components in such a forecasting methodology: one analyzing the economic environment, one predicting modal choice according to commodity characteristics, and one estimating average shipment sizes for each commodity and mode.

First, the economic interrelationships within the system are assessed. This assessment includes considering the movement of commodities between industries and consumers, as well as the spatial distribution of freight origins and destinations within the Texas-Mexico region. Because modal choice is considered to be made with respect to commodity characteristics, estimates for industrial output will be disaggregated into outputs for each commodity. Commodities are defined in terms of abstract attributes referring to their value and handling characteristics. This stage, which is discussed in Chapter 4, will be the most important platform for addressing issues concerning the structural effects of NAFTA and the differences between the U.S. and Mexican economies. It will provide forecasts for the levels of commodity demand between regions within the system, according to the state of the economic system.

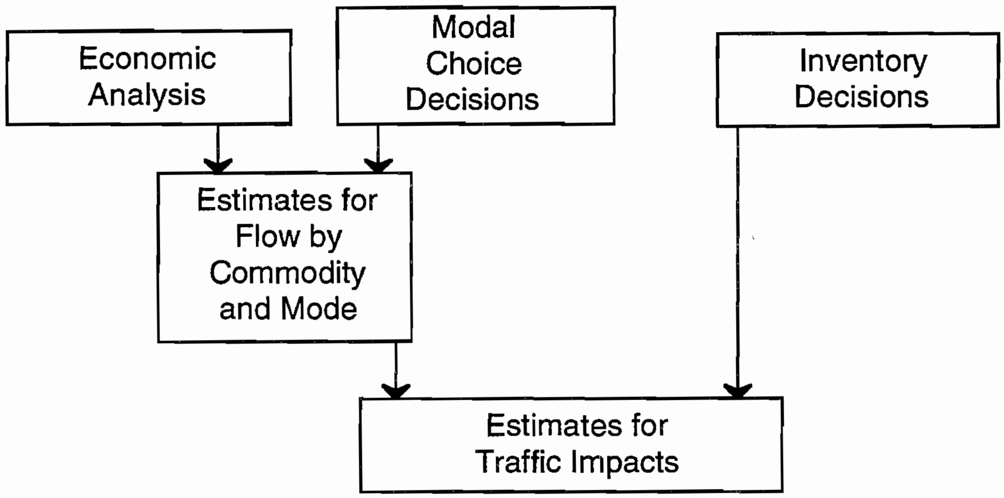


Figure 3.3 Methodology for forecasting freight demand

The second component of the methodology analyzes modal choice decisions for each commodity and each origin-destination pair. This component includes enumerating those factors which determine or constrain modal choice and describing how modal choice decisions reflect commodity characteristics and the behavior of decisionmakers. This part will result in the ability to predict modal choice based on the specification of shipment and modal characteristics.

The results from these first two components are combined in order to generate estimates for the total flow of commodity by mode across the border. The third part of the methodology, described in Chapter 6, translates these estimates into estimates for the traffic impacts associated with these commodity flows. The third component focuses on how receiving parties select a shipment size by considering modal limitations, inventory considerations, and decisionmaker characteristics to be determinants of shipment size choice.

3.5 SUMMARY

This section defined a methodological structure for forecasting freight demand between Texas and Mexico. This structure was developed to address a problem statement and to consider the effects of the border and NAFTA on forecasting freight in this region. These considerations led to the development of a three-part methodology, which predicts freight demand in a way analogous to the decision hierarchy of firms. Because it implicitly examines the economic environment in which modal choice decisions are made, this methodology will be responsive to the effects that NAFTA will have on company decisions — more so than the models discussed in Chapter 2.

CHAPTER 4. INTERREGIONAL INPUT-OUTPUT ANALYSIS

The North American Free Trade Agreement will have an effect on transborder traffic by increasing total trade volume between the United States and Mexico. NAFTA will have an additional effect on the border by changing the structure of the economic relationship between the two nations. By lowering the economic cost of crossing the border, NAFTA may increase the number of cross-border movements involved in the stages of an industrial production process. Consequently, the transportation impact of NAFTA may not be directly proportional to its economic impact. As Section 2.3 showed, many forecasts of NAFTA's transportation impacts on the Texas-Mexico border have failed to address the consequences of this type of structural change.

Because this report strives to develop a methodology capable of forecasting the transportation impacts of NAFTA over a long-run planning horizon, it is critical that these structural issues be addressed. To examine the intersectoral linkages within the Texas-Mexico economic system, interregional input-output analysis is applied. This chapter starts with a theoretical overview of the input-output method, followed by an assessment of three critical assumptions which play a significant role in this methodology's development. Next, the concept of extending input-output analysis across the border region is explored, with a discussion of some associated application and implementation issues. The chapter closes with a summary of how input-output analysis is incorporated into the forecasting methodology.

4.1 INPUT-OUTPUT THEORY

Transportation flows are the result of spatially dispersed activity across and within regions and sectors in an economy. Consequently, an economically-based forecast for freight transportation flows must be derived from some measure of the economy's future activity. The input-output theory is one of a few methods that have been proposed for analyzing economic interdependence between sectors and regions; it is certainly the most frequently cited method in the economic literature.

Proposed by Leontief (Ref 66), the input-output method was developed as a way of quantitatively examining the structural interdependence of the American economy. Its purpose was to look at how industries interact with each other, and to quantify how one industry's activities would influence those of other industries. It is a matrix-based technique which views the economy in an accounting framework. It considers all economic transactions as having a unique purchaser and a unique merchant, such that the sum of all expenditures equals the sum of all receipts.

At the core of the input-output analysis is the transactions matrix, which represents the economic flows from one industrial sector to another. In the upper left corner of this matrix is an $n \times n$ matrix (X) representing the value of flows between n industries in the economy. Each cell x_{ij} represents the value of output produced by industry i that is purchased by industry j. Such purchases include both raw materials, such as fuel purchased by a manufacturing company, and finished products like mechanized farm equipment purchased by agricultural companies. The matrix rows correspond to the outputs of each industrial sector, while the columns reflect each sector's purchases.

Not all industrial demand is accounted for by other industries; there are aggregate inputs to these industries, and also final outputs from these industries. This is captured by annexing rows and columns to X, creating an augmented transactions matrix. For completeness, these rows should be added: gross inventory depletion, imports, payments to government, depreciation allowances, and household supply. In addition, the following columns should be added: gross inventory accumulation, exports to foreign countries, government purchases, gross private capital formation, and household — or final — demand (Ref 67).

An example of a simplified augmented transactions matrix is shown in Table 4.1. Augmented to the X matrix is a column reflecting final demand — Y, the second column from the right. Each entry (X_i) in the final column represents the sum of the output for row i.

The goal of input-output analysis is to translate X into an $n \times n$ technology matrix A, with unique values for each a_{ij} cell. Each cell a_{ij} represents the direct and indirect effects of $1.00 more production in industry j on required inputs from industry i. This technology matrix can be derived through the following matrix equation:

$$X = A \times Y \tag{4.1}$$

To apply the input-output analysis as a forecasting technique, one needs estimates for Y, the final demand vector, for the forecast year. Since most macroeconomic forecasts generate estimates for final demand in terms of dollars and not units of output, this calculation is straightforward. The product of the A and Y matrices will yield a new transactions matrix X, which will indicate what goods movements need to occur between industries in order to meet the requirements of final demand.

Table 4.1 Augmented transactions matrix

	Industry Purchasing (j)				
Industry Producing (i)	Agriculture (1)	Manufacturing (2)	Trade & Services (3)	Final Demand (Y_i)	Total Gross Output (X_i)
Agriculture (1)	1	3	2	6	12
Manufacturing (2)	4	6	4	10	24
Trade & Services (3)	2	3	5	8	18

All figures are in billions of dollars.

The main strength of the input-output method is its internal consistency. Owing to the accounting framework used in its application, each transactions matrix has two consistency tests which can be applied:

$$\sum_j x_{ij} + Y_i \equiv X_i \tag{4.2}$$

and

$$\sum_i x_{ij} + V_j \equiv X_j \tag{4.3}$$

where V_j = value added to industry j

The internal consistency holds as long as the matrix is constructed in such a way to ensure that all economic flows are represented.

4.2 LIMITATIONS AND ASSUMPTIONS

Its conceptual simplicity has made the input-output method the most frequently applied tool for intersectoral economic analysis. Its simplicity conceals three basic assumptions which must be examined with care, especially in the context of this methodology. First, each column and row is assumed to represent a homogenous product. Second, all production technologies are assumed to have constant returns to scale. Third, the input-output model is fundamentally static. These three assumptions, and the consequences they imply for developing the methodology, are discussed in this section.

4.2.1 Industry and Commodity Definition

As was mentioned in Chapter 3, the methodology presented in this report assumes that modal choice depends upon commodity characteristics. For the input-output method to be used, then, its rows and columns should correspond to these commodities. If the input-output analysis abides with a strict assumption of product homogeneity, however, the resulting transaction matrix will contain tens of thousands of rows and columns. Each industry may produce hundreds or thousands of different commodities, each with slightly (or greatly) different transportation-related characteristics. For example, within the agriculture industry there is much heterogeneity in commodity characteristics, such as perishability (as in comparing strawberries and wheat) and value per weight (like comparing imported fruit and potatoes).

In the interest of conversing both computational and data-gathering efforts, some aggregation is recommended. Since the methodology develops a commodity-oriented modal choice forecast, it makes sense to aggregate commodities according to those characteristics which influence modal choice. However, since the input-output framework is designed to model economic interactions between sectors, the aggregation of commodities into commodity groups cannot be blind to the industrial sectors in which commodities are economically included. For example, wheat and coal may have some similar transportation-related characteristics, but their roles as inputs to other sectors differ considerably.

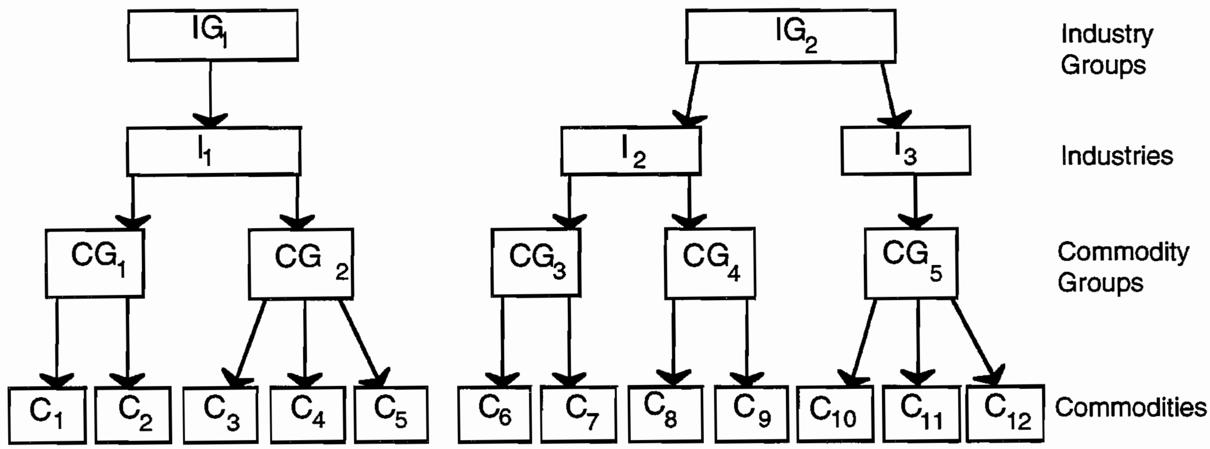


Figure 4.1 Disaggregation for industry groups

Figure 4.1 describes a hierarchy for aggregation. At the most aggregate level are industry groups, of which analysts count between twelve and fifteen within a developed economy. Within each industry group there are industries, or commodity groups. This is the level of aggregation at which modeling of modal choice is typically done, as most commodity-based studies have generally used between 20 and 100 commodity classifications. Each commodity group can be divided into individual commodities, and then each commodity can be subdivided into individual products. Each level of disaggregation will better isolate the specific transportation-related commodity characteristics which affect modal choice; however, each level comes with an exponential increase in the cost of data collection.

For aggregating commodities into commodity groups, there are two sets of characteristics which should be considered: physical characteristics and economic characteristics.

Physical Characteristics: A commodity's physical characteristics will restrict the modes which may be used for shipment. These characteristics relate to size, handling, and preservation of the commodity. First, a commodity will be defined in terms of its size, such as by its density and weight. Weight and density provide limits for minimum and maximum shipment sizes that may be used for a given vehicle size. As a commodity's weight increases, the more likely it will violate a maximum weight restriction for a mode. As its density decreases, then the commodity may be able to fill the volume of a vehicle without violating any maximum weight limits. Next, a commodity can be defined by its handling requirements, such as its form and fragility. The commodity can be transported in many forms, such as liquid, liquid suspension (like grain transported via pipeline by being immersed in water), bulk solid, palletized solid, or gaseous. Fragile commodities may require additional packaging and protection against shock during loading, transit, and unloading. Finally, the commodity can be described by its need for preservation during transit. This includes factors such as volatility, perishability, and the need for temperature control. These factors will dictate the needs for specialized equipment and packaging, as well as for expedited or protected transit.

Economic Characteristics: Each commodity will also have several economic characteristics which define it. The most obvious of these is the commodity value, which may be expressed per unit weight, per unit of shipment, or per shipment. However, a commodity has other economic characteristics. First, there are special transport-related costs associated with a commodity, which occur only once a commodity is shipped. These include in-transit insurance costs, packaging costs, and any commodity-specific pick-up and delivery charges. Second, each commodity has inventory-related economic characteristics, such as storage cost per unit and shelf life. As storage cost increases and shelf life decreases, a commodity should be shipped in smaller shipment sizes. Finally, each commodity can also be defined by market characteristics, such as seasonality, annual product demand, and geographical distribution of demand. These characteristics will determine the quantity of the commodity which will need to move in a given time frame, and how this demand needs to be spatially and temporally transported.

It is important to remember that true industry homogeneity is only realizable in a theoretical sense. Moreover, due to uncertainty in the technology matrix A, strict homogeneity will be unlikely to enhance the model's predictive capabilities. However, each commodity group should have relative homogeneity and close substitutability among its outputs (Ref 68). There should be significantly less variance within a commodity group than between groups, in both industrial and transportation-related characteristics.

4.2.2 Economies of Scale

The a_{ij} coefficients imply a constant production relationship between sectors of the economy, such that these multipliers of economic activity will not change with output. In other words, marginal costs of production for any industry neither increase nor decrease with the quantity of industrial output. This implies that, within a given region, transportation and production costs are constant with respect to the scale of production. Moreover, these coefficients assume that there are no synergistic relations between industries that cannot be accounted for in the input-output matrix. In other words, the input-output method assumes that total economic effects are the sum of the individual effects.

For this to be true, excess capacity must exist throughout each industry's supply chain, including production, transportation, and labor (Refs 69, 70). Each industry must be able to expand production without any unusual cost penalties. There should be sufficient capacity in the transportation system such that freight rates and network congestion will both be unaffected by increases in industrial output. Finally, there must be sufficient labor supply to ensure that any new demand for workers will not result in increases in the average wage. As long as excess capacity is available, the only constraint that will exist on production capacity will be the demand that exists for that commodity.

In the border economy, there is little evidence about a shortage of productive capacity. Labor supply at the border has been cited as an issue which has led to the development of maquiladoras in Mexico's interior. This shift in maquila location has occurred largely not because of the quantity of labor, but rather the quality. There has been no evidence of significant demand-induced wage inflation on either side of the border. It is unlikely that such a problem will develop over the forecast horizon. Transportation system capacity is an issue at some border crossings and on some key links in the border region. Because this methodology does not estimate transportation impacts for specific border crossings, it is more important to consider whether or not the nature or degree of transportation congestion for the network as a whole will change over the forecast horizon. NAFTA would likely lead to an increase in congestion at selected border crossings, but this may be more than offset by the use of ITS technologies to accelerate processing times. As the border crossings become more efficient, there should be less queuing and delays on the network links leading to the crossings. Until integration of ITS technologies into border crossing procedures has been successfully implemented on a large scale, however, it is assumed that congestion in the transportation system will not change over the forecast horizon; therefore, the assumption of constant economies of scale will be valid for this region.

4.2.3 Dynamic Analysis

The input-output model was originally designed as a static analysis tool, since the a_{ij}'s are assumed to be fixed over time. In applying the input-output model to a 20-year planning forecast, however, many a_{ij} coefficients will change, and some of them dramatically. This section discusses three primary influences which will cause these coefficients to change over time: production technology, new and emerging industries, and spatial disequilibrium.

Production Technology: Beyond a short-run time frame, change in the mix of factors used in production is inevitable. This change may occur for one of several reasons: changes in relative input prices; the effects of technological innovation on production; or an increase in the technological knowledge of the labor force (Ref 67). Input-output analysis cannot forecast the influence of technological change on the production functions of the various industrial sectors. Rapid technological change or a shift in production technology, such as when a maquiladora switches between capital-intensive and labor-intensive operations depending upon relative factor costs, reduces the accuracy of any forecasts generated by the model.

New and Emerging Industries: Another concern with dynamic analysis is the development of new and emerging industries and their impact on the economy's performance. A new industry will reduce demand for output from another industry as a subsidiary effect, but may augment output demand for other industries whose output is complementary to the new industry's output. For example, the introduction of the automobile in the late 19th century subtracted demand for other transportation modes, but created additional demand for petroleum products.

The forecasting problem for new and emerging industries is to identify the interdependence of new industries with existing industries. The ratio of inputs into a new industry will be difficult to predict — the initial stages of product manufacturing are generally labor-intensive until capital is more efficiently integrated into production. The distribution of output could be assumed to be proportional to already observed trade flows, although not necessarily. For example, microcomputer demand was primarily as a result of the research services industry, but computer technology was soon found to be applicable to nearly every other industry as well. As an emerging industry matures and its industry leaders become more aware of potential efficiencies in production, one could expect the industry's a_{ij} coefficients to change. This property is shared by all industries, but will be most acutely noticed in new and emerging industries.

It is difficult to forecast the proportion of trade across the Texas-Mexico border in the forecast year which will result from "new and emerging" industries. In the short run, new and emerging industries would, by definition, characterize a very small portion of total shipments in the short term. Over a twenty-year planning horizon, however, these developing industries will alter the intersectoral relationships within the economy, as well as reshape the economy's aggregate demand for goods. If an industry's development is significant enough during the planning horizon — such as the tremendous growth in the telecommunications and computer equipment industries within the past twenty years — the input-output model will likely need to be completely re-calibrated, with a new set of a_{ij}'s being developed from scratch.

Spatial disequilibrium: The input-output model assumes a rigid spatial framework for all economic actors; markets, producers, and suppliers will stay in the same general area. This state of spatial equilibrium depends on stability in the factor costs that each industry faces, as well as in the transportation system and tariff structures (Ref 58). As factor prices and product revenues change, there will be a tendency toward what could be called "spatial disequilibrium" — a state where industries are moving operations and demand patterns are shifting in response to market conditions. This is characteristic of a long-run view of firms' decisionmaking processes.

Spatial disequilibrium can result from changes in any factor prices, including labor, transportation, natural resources, and capital. As an example, consider the maquiladoras discussed in Chapter 2. Maquiladoras are not necessarily additions to manufacturing capacity, reflecting economic growth, as much as they are substitutes for less efficient plants in other regions which require more expensive labor. The effect of transportation costs on spatial equilibrium can be seen by examining how the growth in air transport demand has encouraged foreign trade and multinational corporations, as these are found to be more cost-effective than closed economies and locally operated companies. Transportation costs have changed not only the scope of industries, they have also changed their internal structure, relating to the location of warehousing and manufacturing facilities relative to markets. These costs can even determine industry concentration where lower transportation costs serve to encourage economies of scale.

Assuming spatial equilibrium requires that transportation costs and other factor prices do not change significantly over time (Ref 59). This is a very stringent assumption, especially for a twenty-year forecast horizon. It prevents a company from changing the spatial distribution of its production functions in response to a change in transportation costs or other input prices. It prevents any unilateral relocation during the analysis period of any industrial operations. Finally, it prevents any shifts in modal share over the analysis period.

Synopsis: The effects of technological change, new and emerging industries, and spatial disequilibrium can clearly not be ignored with respect to a long-range forecast for the Texas-Mexico border region. Therefore, the input-output methodology must allow for the a_{ij} coefficients to be dynamically sensitive.

Carter (Ref 71) proposed one method for incorporating dynamic sensitivity into Leontief's original open input-output model. This is done by first restating Leontief's model in matrix notation, as:

$$(I - A)X(t) - BX(t) = Y(t) \tag{4.4}$$

where A = matrix of technological coefficients

B = matrix of capital, or incremental, coefficients

X = vector of output

Y = vector of final demand

t = time

A dynamic model would reflect how changes in output interact with capital flows over time:

$$(I - A)X(t) - B\left(X(t) - X(t-1)\right) = Y(t) \tag{4.5}$$

At any given time, there is a matrix of technological coefficients which represents the best practice in industrial technology; this will be referred to as A'. This "best practice" matrix will include the mix of all factors used in production, including transportation costs. Industries will be in a continual process of adjusting their technology toward the state-of-the-art technology represented by A'. Then the technology in use at time t would be a weighted average of the best practice technology, A', and the previous state of technology, $A(t\text{-}1)$. Therefore:

$$(I - A')X(t) - B\left(X(t) - X(t-1)\right) = Y(t) + \left(A(t-1) - A'\right)X(t-1) \tag{4.6}$$

To complete a dynamic input-output analysis, then, is to determine how the incremental coefficients, B, are chosen. This procedure will be discussed in Chapter 7, in conjunction with other issues relating to implementing this methodology.

4.3 INTERREGIONAL ANALYSIS

Freight movement will exist between regions for one of two reasons: first, to cover the inequalities in the geographic distribution of population, income, and resources, and second, to embrace the indivisibilities of production and consequent economies of scale in operation (Ref 59). As discussed so far, the input-output model has been presented strictly as a method for analyzing intersectoral flows within a single region. This would not allow the analyst to see any patterns in freight movement between regions. The input-output method can, however, be used to analyze intersectoral flows between regions as well. This is especially critical in this forecast, where the system under consideration — the United States and Mexico — is not homogeneous.

There are at least three ways in which input-output analysis can be extended interregionally: the balanced regional model, the pure interregional model, and the international model. The balanced regional model takes a national input-output model table and divides it into its component regions. This allows the analyst to determine the regional implications of national policies, such as the impact of NAFTA on the Texas-Mexico border. The pure interregional model, also called the Isard model, aggregates a number of regional input-output tables to determine the national implications of regional policies or projections. This model creates distinct commodities for each region, allowing each sector to acquire a given input in different proportions from different regions. The international model defines a transaction matrix for a given region of analysis. From this matrix, the exports column and imports row are divided by region or nation.

Chenery (Ref 72) stated four assumptions which may be used to compare interregional models. Table 4.2 evaluates each of these interregional models according to these four assumptions. The first assumption is that all productive sectors must be classified as either national or regional. For example, certain products are produced locally for local consumption, such as municipal water, while others, like petroleum, are used in many regions but are produced in few. The second assumption is that, for industries classified as regional, the region's demand will be fully satisfied from production within that region. The demand for a regional product like milk in Texas, for example, is unlikely to be satisfied with dairy products from Alberta. This is not always true, especially for nonhomogeneous products like automobiles. The United States is capable of producing enough automobiles to meet all of its demand; however, due to product differentiation, Americans import automobiles from other nations (Ref 70). Third, the production pattern of national commodities is assumed to be fixed by region regardless of the location of demand. Given nonzero transportation costs, however, it would make sense that production patterns would reflect the concentration of demand. Finally, regional input coefficients are assumed to be the same as national coefficients. Because Mexican manufacturing is more labor-intensive than American manufacturing, this assumption will not be valid.

Of the three models listed in the table, the pure interregional model is the only one which allows the analysis to give due consideration to the heterogeneity of the American and Mexican economies. It should be noted that it is the most data-intensive of the three models, and to the author's knowledge has therefore not yet been successfully applied.

4.4 METHODOLOGICAL INTEGRATION

It is clear that the input-output method, by itself, is insufficient to develop reasonably accurate, long-term forecasts for trade between the United States and Mexico. The static effects of regional diversity and the dynamic effects of NAFTA implementation and technological change require the method to be enhanced to include interregional and dynamic elements, which were discussed in Sections 4.2 and 4.3. Since the dynamic effects will vary by region, these components must be employed sequentially. This process is indicated in Figure 4.2.

Table 4.2 Assumptions in interregional analysis methods

	Balanced Regional	Pure Interregional	International
Assumption #1: All productive sectors are classified as either national or regional	No	No	Yes
Assumption #2: Demand for regional industries must be satisfied regionally	Yes	No	Yes
Assumption #3: Production pattern of national commodities is fixed by region regardless of location of demand	Yes	No	Yes
Assumption #4: Regional coefficients equal national coefficients	No	No	Yes

Assumptions referred to in Chenery (Ref 72)

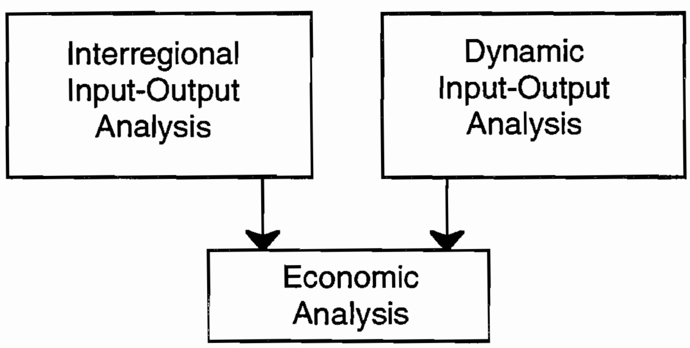


Figure 4.2 Components of economic forecasting

The first step is to develop an interregional input-output table. Developing this table requires defining the number of regions and industries within the system. Based on the objective and system definition specified in Section 3.1, it would be appropriate to define three regions within the system: the western United States, the eastern United States, and Mexico. The distinction between the western and eastern United States is not relevant to the extent that there would be remarkable differences in the technological coefficients (a_{ij}) between regions; in fact, such differences should be negligible. This distinction is made to acknowledge that there are clear land corridors of trade between the United States and Mexico. In general, the corridors that pass through Texas serve locations within the eastern United States, while the western United States is served through corridors passing through other states. Figure 4.3 demonstrates this by showing how trade-related truck traffic is concentrated on the U.S. side of the border.

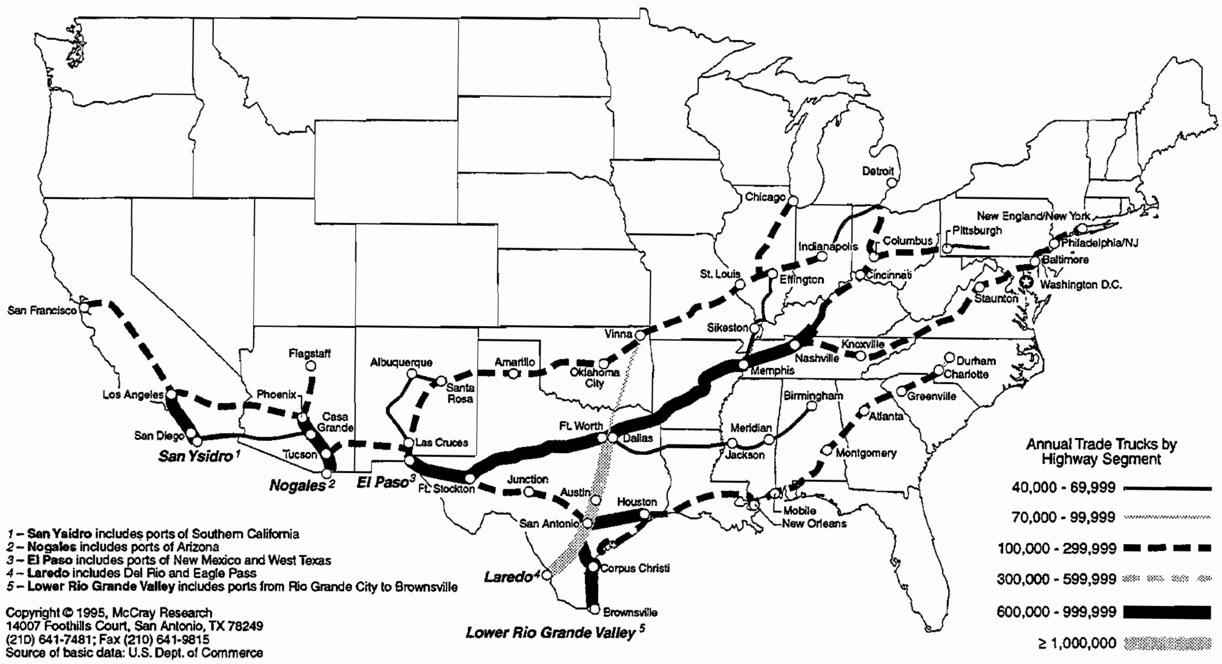


Figure 4.3 Dominant U.S.-Mexico highway trade corridors (Source: McCray, 1995)

The second step is to evaluate the dynamic effects of NAFTA implementation and technological change on the interregional matrix. NAFTA is expected to cause the movement of productive capacity between regions over the forecast horizon. Consequently, the matrices representing incremental technological change and state-of-the-art industrial practice, B and A', will be unique for each pair of regions. Given Y_d for a forecast year τ, one can generate $X(\tau)$ as part of a new, interregional transactions matrix. Within the forecast horizon, therefore, interim forecasts may be generated, if B is expected to change within the period. Therefore, the dynamic input-output analysis may be performed according to the degree in which the analyst can predict the rate at which change will occur in the economic structure of the system.

The culmination of the interregional and dynamic input-output analysis will yield X for the forecast year for each pair of regions within the system. Each cell x_{ij}^{kl} corresponds to the value of industry i's products sold to industry j between regions k and l. Therefore, one has commodity-specific estimates of freight flow between regions within the system:

$$\sum_j x_{ij}^{kl} = x_i^{kl} \tag{4.7}$$

These estimates for commodity flows are analogous to the market demand which faces firms in each industry. This creates the economic environment in which firms make intermediate-run and short-run decisions, such as modal choice and shipment size decisions. These decisions are discussed in Chapters 5 and 6.

4.5 SUMMARY

This chapter has proposed using the input-output method to forecast demand for goods between regions. The input-output method is an accounting-based framework which operates best under careful industry classification, with stringent assumptions of constant economies of scale and static economic behavior. These assumptions were addressed, along with the enhancements which have been made in the method to enable it to be applied in dynamic and interregional situations. These enhancements enable the analysis to generate estimates of freight flow by commodity between regions within the system, making it a vital part of forecasting the transportation impacts of NAFTA on the Texas-Mexico border.

CHAPTER 5. MODAL CHOICE DECISIONS

Rational decisionmaking generally follows a process similar to that depicted in Figure 5.1. First, a decisionmaker identifies alternatives, generating a choice set through information gathering. Second, the decisionmaker enumerates and quantifies all attributes of each relevant modal alternative. Based on experiential, attitudinal, and environmental factors, the decisionmaker perceives these attributes and makes an evaluation of the preferred choice by applying a decision rule. The outcome is that the preferred choice is selected.

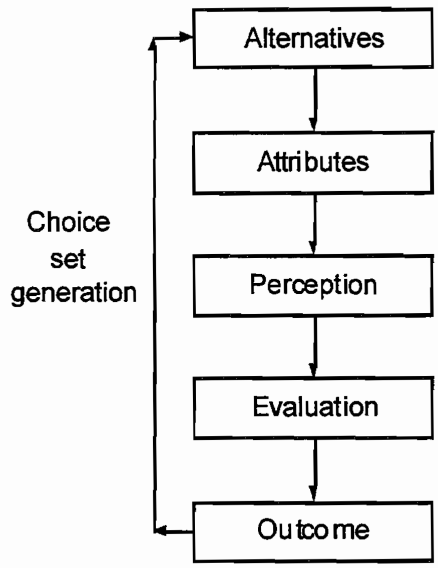
This chapter examines how firms make modal choice decisions by following this same structure. First, the identification of modal choice decisionmakers and of the parties that influence their decision will be examined. This is followed by a brief, generic description of the modal alternatives in the choice set which is available to shippers. Attributes which are frequently ranked as important in modal choice decisions are investigated in relation to the Texas-Mexico border freight market and to their ability to be modeled. The perception of the attractiveness of each modal alternative according to each attribute is discussed. This is followed by an assessment of how the alternatives are evaluated according to compensatory decision rules, and by an identification of those attributes which are most critical to the modal choice decision. The chapter closes with a discussion of how the analysis of modal choice decisions is integrated into the methodological structure introduced in section 3.4.

5.1 DECISIONMAKERS

Freight transportation, like any other unregulated market, is governed by the law of supply and demand. All actors in the market, specifically shippers and carriers, will interact in such a way that the market will, if unobstructed, tend toward equilibrium. Shippers and carriers, freight forwarders and brokers, and various governmental structures all have roles in the decisionmaking process. Unlike some of the network models which were discussed in section 2.4.2, each of these actors will seek to maximize his/her own objective function.

While both shippers and carriers strive to minimize costs, their optimal strategies, given a pattern of behavior from the other side of the market, will differ. This is because shippers and carriers view a transportation network differently. Table 5.1 lists how carriers and shippers view their objectives in different terms. As Sheffi (Ref 74) put it, "transportation providers operate a network of *legs* while shippers are interested only in costs, flows, and service levels on *lanes*." Carriers will be concerned about their profitability on each leg or link of a transportation network, and are thus highly concerned about routing of vehicles and their optimal usage. Shippers are not as concerned about routing, unless it increases the shipment's costs, handling time, or probability of loss and damage.

In the freight transportation market, carriers — and, to some extent, government agencies — act to supply transportation, and shippers demand transportation services. This market is depicted in Figure 5.2. According to classical economics, a shortage of transportation capacity, such as equipment, road capacity, or customs processing capability, would result from carriers charging freight rates (P_0) below the market equilibrium (P_{eq}). Because the price is below the market-clearing level, shippers are demanding more freight transportation, resulting in a higher utilization of equipment. At P_0, carriers will not make as much profit; hence, since shippers are demanding more capacity than carriers are providing, carriers will take advantage of the shortage to raise rates, which would induce an increase in the transportation supply, until equilibrium is reached (Q_{eq}, P_{eq}).



From: Mahmassani (Ref 73)

Figure 5.1 Decisionmaking framework

Table 5.1 Carrier/shipper interactions (Ref 74)

Carrier	**Shipper**
Coverage (locations served; terminals) Fleet size	Collection/distribution network structure (warehousing; routing and consolidation process) Administrative/contracting options
Vehicle type and size (container size)	Shipment size and inventory levels
Transit time Dispatch policies (schedules and frequencies)	In-transit inventory cost Fluctuation/anticipation stock levels Customer service
Reliability (of transit time; handling; of equipment)	Stock-out costs/safety stock Expediting shipment costs
Rates Discount level	Transportation costs Inventory levels
Information services	Stock-out control Shipment expediting ability

In the short run, neither shippers nor carriers are price-takers. Each has some market power to negotiate rates and service attributes. Accordingly, each set of actors can have critical impacts on freight market equilibrium. The use of carrier contracts and capital associated with transportation supply means that the short-run supply curve of freight transportation is not perfectly elastic. On the other hand, shippers often strive to, and are able to, negotiate rate discounts.

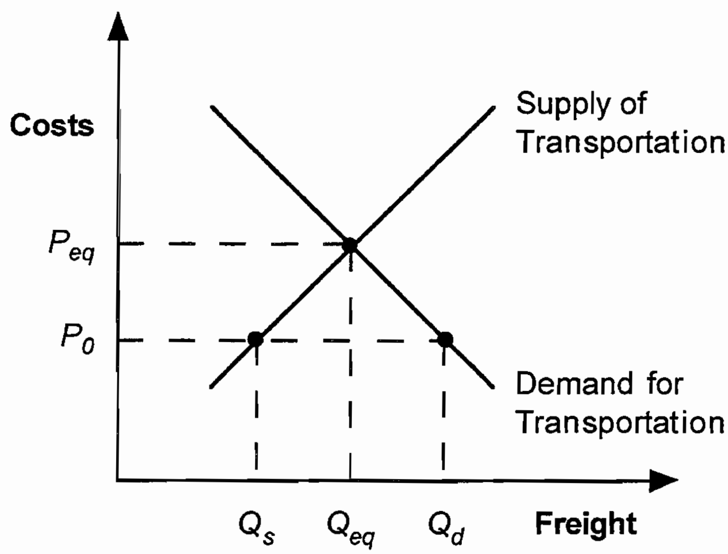


Figure 5.2 Supply and demand in the market for freight transportation

There are three principal methods by which modal choice might be determined. The first is when the shipper acts as the carrier, providing its own vehicles, loading and unloading equipment, and facilities. In this case, the shipper will be the ultimate decisionmaker on modal choice. A second case is when a shipper directly contracts with a carrier. In such cases, the shipper may specify a mode if the shipment has needs for special handling or for unloading equipment, or if the shipper has an intrinsic bias for or against a specific mode. A shipper, however, will often not instruct a carrier to choose a specific mode, in order to allow the carrier to tailor a transportation alternative to best meet the service requirements of the shipper. A third case is when the shipper contracts a third party, called a freight forwarder, to handle shipment services. The forwarder consolidates the shipments of many shippers in order to take advantage of a carrier's cheaper marginal freight rates for heavier shipments. To the shipper, the freight forwarder acts like a carrier; the freight forwarder has the responsibility of ensuring the delivery of the shipment according to the shipper's guidelines. To the carrier, however, the freight forwarder acts like a shipper. The forwarder may or may not have a specific modal request, based on the shipment's service requirements or on previous experience.

For international shipments, the use of freight forwarders and third-party logistics operations is relatively common, owing to the documentation requirements and operations restrictions on freight carriers. Davies (Ref 75) found that between 80 and 95 percent of air and 50 percent of surface freight shipments relied on freight forwarders. Before NAFTA, U.S. transportation carriers were excluded from operating in Mexico. Consequently, 60 percent of maquiladora managers have relied almost exclusively on third-party logistics companies for providing transportation services (Ref 4).

5.2 CHOICE SET

Once the primary decisionmaker has been identified, the choice set that the decisionmaker faces should be considered next. The choice set will be comprised of two principal choices: modal choice and shipment size choice. Modal choice is discussed in this section; shipment size choice is discussed in Chapter 6, in conjunction with a review of logistics and inventory theory.

For each shipper, the modal choice set consists of all known, accessible, and available modal alternatives. This description implies two important things about the choice set in this decisionmaking process. First, the contents of the choice set depends on the information the shipper has about modal alternatives. Second, because shippers are located in unique positions with respect to the transportation infrastructure and have unique considerations of target markets and commodities, the choice set is uniquely defined for each decisionmaker. This section analyzes some currently available modal options and their performance attributes.

5.2.1 Motor Carriers

As stated in Chapter 2, motor carriers, or trucks, are the dominant mode in cross-border freight. Motor carriers are the mode of choice for most of the major trade corridors between Mexico and the United States (see Appendix A, Table A-8), as well as for most commodity groups (Tables 2.3, 2.4). In fact, many commodities are shipped exclusively via truck, regardless of the availability of alternative modes. Motor carriers are the most flexible of modal alternatives, capable of offering door-to-door service on all ranges of shipment distances for a large class of shipment sizes. They offer decent operating speeds, excellent accessibility and equipment availability, competitive rates, low in-transit damage, and reliability in transport (Ref 76).

Within the mode of motor carriage, several choices are available, each with distinctive characteristics. The first distinction to be made is between truckload (TL) and less-than-truckload (LTL) shipments. Truckload carriers specialize in large shipments, offering direct service from the supplier to the customer. Less-than-truckload carriers, also known as common carriers, consolidate smaller shipments from many shippers into larger shipments at terminals. This transfer often involves a change in vehicles and or drivers for the shipment. Due to this consolidation process, LTL carriers have a time handicap compared to TL carriers, corresponding to handling time for the consolidated cargoes (Ref 77). Nevertheless, motor carriers are heavily engaged in LTL shipments (Ref 78).

For truckload shipments, a distinction may be made between private carriers and for-hire carriers. Private carriage is used by shippers which operate their own fleet of vehicles, and act as a carrier for their own shipments. For-hire carriage is for companies whose shipments are too infrequent to merit fleet ownership by the firm; these services will usually be arranged by contract. Private transport affords several advantages over for-hire carriers, including at-cost shipping, faster delivery on rush shipments, and better coordination with production schedules. However, private transport cannot take advantage of economies of scale, especially for smaller, infrequent shipments. Therefore, it is only used when transportation costs are a large percentage of total costs (Ref 36).

5.2.2 Rail

Railroads offer similar service options to motor carriers. They offer carload (CL) service and less-than-carload (LCL) service. Firms can also rent unit trains, analogous to a privately operated truck, to ship commodities as diverse as coal and automobile parts. All of these services are contingent upon the firm's access to a railroad siding. If the firm does not have a siding and appropriate loading facilities, it would likely need to use trucks to get the freight to the nearest rail terminal, resulting in some sort of intermodal shipment.

Because of siding access and also because of the high fixed cost associated with rail shipments, smaller shipments will generally go by truck instead of rail. Friedlaender and Spady (Ref 34) found that the demands for rail (of any type) and LTL were largely independent, and were perhaps complementary. This is because smaller shipments are inefficient and slow on rail, while large shipments will not use LTL. Rail will most often compete with TL carriers. With the exception of LTL trailers carried on rail cars, rail will generally not carry less-than-vehicle-load shipments.

Rail has had a poor reputation among many shippers, a result of a perceived unreliability in transit times, higher damage claims during shipping, and inflexibility in service. More recently, however, improvements in equipment tracking, customer service, and rolling stock and track maintenance have improved its image considerably. Rail is slower than motor carriage, primarily a result of the time spent at interchanges, terminals, and switching yards. Consequently, motor carriers offer rates 15–20 percent higher than rails for "comparable" service. However, rail does have advantages in its lower energy consumption, a high level of safety on the line-haul, and economic viability in carrying large volumes of bulky cargo. Rail usually has a significant modal share in commodities with low value, long distance, high density, large volume shipments (Ref 78).

Trains have a higher fixed cost per vehicle-trip than do trucks; consequently, consolidation and routing of rail cars is a much more important issue for railroads than consolidation is for motor carriers. This consolidation introduces a transit time handicap, and may introduce variability in transit time. Railroads also have issues of network capacity different from those facing motor carriers. Motor carriers will face capacity issues only at consolidation and handling terminals, based on their storage and processing capacity. Railroads, on the other hand, may face network congestion due to single-tracking, blocked sidings, equipment failures, and many other factors. As railroads have worked to regain freight market share, this has been the primary emphasis on which they have striven to improve customer service.

5.2.3 Air

Recent years have seen an emphasis on quick freight movement, and this has brought about tremendous growth in air freight service. Air freight, generally priced by weight, is significantly more expensive than other modal alternatives, but it is also significantly quicker. Because it takes about one pound of fuel to transport four pounds of air cargo, bulky and low-value shipments will not travel by air (Ref 79). Shipments that will be flown include high-value, fragile and/or perishable commodities with a high time value associated with their transit, such as certain types of produce, high-tech electronics, and replacement parts for factories.

Unlike other modes, air transport can guarantee same-day delivery for many markets and many products. Air cargo, like many rail movements, depends significantly on economies of scale. As long as there is a sufficient volume of freight, air cargo can be price-competitive with other modes of transport and offer superior service.

However, air is also like rail in that it is restricted to terminal-to-terminal service, rather than door-to-door service like motor carriers. As was discussed in Chapter 2, airport accessibility is a critical issue for Mexican exporters, and will likely hamper the short-term growth of air cargo in the Texas-Mexico freight market.

5.2.4 Sea

Maritime transport is cheaper and slower than virtually any other transportation mode. However, it is also among the most inflexible modes, since few industrial firms in Mexico have direct port access. Maritime shipments have high terminal costs, high inventory costs (due to the slow transit time), and greater transit time variability due to weather conditions. At sea, shipments have a very low loss and damage rate, but theft and pilferage are a concern at terminals and ports.

Shipments transported by water are generally large shipments with low-to-medium value, or long distance shipments where in-transit commodity depreciation is not a critical issue. This is a similar market to rail's traditional market (Ref 80). Petroleum, coal, coke, sand, gravel, iron ore, and steel are among those commodities which are frequently shipped by sea (Ref 78).

5.2.5 Intermodal

An intermodal shipment is one in which two or more dissimilar modes are used in the transport of a shipment from an origin to its destination. Intermodal shipments will be characterized by links and nodes along the movement: the links are the line-haul segments where the shipment travels by a single mode, and the nodes are points at which the shipment is transferred between modes. They can involve either a physical transfer of items from one mode to another, or a transfer of a vehicle to another mode.

Intermodal can compete with single-mode transportation — especially TL service on long distance shipments (Ref 81) — only as long as it offers superior performance to single-mode through attributes such as lower rates, more reliable transport times, and better geographic coverage. The transfer time between modes means that intermodal is generally competitive over longer haul shipments.

Critical to the success of intermodal is what happens at interchange or transfer points, due to the time and handling involved in the transfer. Several intermodal facilities have been built on the Texas side of the border in the past few years, specializing in transfers between rail and motor carrier modes. Accordingly, the share of intermodal on long haul domestic shipments has increased gradually over the past few years (Refs 81, 82). As Mexico adds intermodal terminals to its infrastructure, intermodal's share of the cross-border freight market should increase.

Intermodal growth will be encouraged by how well facilities can accommodate containerization. Containerized cargo can be moved by rail (also known as container-on-flat-car, or COFC), motor carriers, maritime transport, and even air. Mexico's ports are not as capable of handling containerized cargo as are United States ports; in fact, many Mexican ports lack even a crane to load and unload containers.

Perhaps the most common example of intermodal transport between Mexico and Texas involves trailer-on-flat-car (TOFC, or piggyback) rail service. A motor carrier trailer will move a shipment to an intermodal ramp, where it is loaded onto a flat rail car. The trailer is transported on rail to another ramp, for unloading and delivery to its final destination by truck. This combines the lower rates of line-haul rail with the convenience and accessibility of motor carriers.

There are numerous other methods of intermodal transport (Ref 79). For truck-rail intermodal movements — the most common transborder combination — there are fourteen types of piggyback service in addition to several other possibilities, including RoadRailers, vehicles which are designed like conventional highway semitrailers with a pair of steel railroad wheels so they could use track as well; bulk cargo transfer; bulk container transfer; and transloading, or the breaking of a bulk shipment from a vehicle of one mode to that of another mode at a transfer point. Double-stacking, which is the loading of one trailer on top of another on a flat car, has helped rail to improve its cost-efficiency, although double-stack service is unavailable in certain areas due to issues of vertical clearance in tunnels and under bridges. For maritime intermodal movements, there is cellular service, where all cargo must be containerized; roll-on-roll-off vessels, where cargo can be transported on wheels and more directly transferred from the ship; and breakbulk vessels.

5.2.6 Abstract Mode Framework

A forecasting methodology must take into account how the choice set may change during the forecast horizon. This is true in freight transportation, especially as intermodal has become more frequently used and more sophisticated in nature over the past ten years.

Consequently, Quandt and Baumol's (Ref 83) abstract mode framework should be considered as a way of formulating modal choice. Quandt and Baumol postulate that modes can be characterized only by their attributes, and that it is the attributes of each mode, not the mode itself, which will determine modal choice. Using abstract modes has two principal advantages. First, it does not limit the analyst to consider only existing modal alternatives. New alternatives can be easily considered by determining appropriate values for each of the attributes by which modes are defined. These new "modes" can be substituted into the formulation to generate demand estimates for modes that might exist. Second, it allows the analyst to consider the impact of policy or operational changes at the modal level on modal selection. For example, a new switching technology may allow trains to switch cars more efficiently at yards, reducing the variability in transit time. An abstract mode formulation can help quantify these effects.

The most important objection to abstract mode theory is its assumption of modal neutrality, which implies that there is no inherent favoritism of one mode over another. In fact, shippers often do not view modal choice in such abstract terms, and the previous performance of a mode with respect to customer expectations can affect the mode's future demand. In other words, the perception of the modal attributes may be more relevant than the values of the attributes themselves, such as was demonstrated in Miklius and Casavant (Ref 84). For a sample of over 2,500 domestic cherry shipments, they found there was no significant difference in transit time variability between truck and rail modes. Yet, when shippers were surveyed as to the perceived variability in transit time for each mode, respondents said that rail was considerably more unreliable with respect to transit time than truck was. It is difficult for the abstract mode framework to accommodate such perceptual differences.

Other objections to the abstract mode theory have been raised in the literature (Refs 85, 86, 22). First, the resulting choice hierarchy is often counterintuitive when a new mode is introduced. By changing the attributes of a mode other than a mode *m*, the demand for mode *m* will not be changed. At the same time, introduction of a new mode could increase the demand for existing modes. Second, the abstract mode model is not derivable from economic theory. Third, the number of trips made is not necessarily based on the freight rates. This does not reflect that firms may elect to use larger shipment sizes to reduce freight costs, or that there are long-term spatial adjustments which would reduce the demand for freight.

These objections question how demand for freight is viewed in the context of a firm's decisionmaking hierarchy. In the short run, when a firm cannot adjust the location of its facilities and markets, freight demand is essentially a fixed quantity which will be distributed among transportation modes according to their attributes. In other words, the short-run demand for freight is inelastic to price and service attributes. If the price for all modal alternatives increases in the short run, the firm is not able to substitute another factor input of production for transportation. As firms adjust the spatial distribution of their facilities in the long run, freight demand is no longer a fixed quantity. As rates are driven lower and service improves through better coordination between modal usage and shippers, firms may choose to leave their operations and markets relatively dispersed and distant in order to take advantage of cheaper factor costs for labor, capital and natural resources. On the other hand, as rates increase due to fuel and infrastructure costs, there may be a greater consolidation of production facilities, and a tendency for producers to collocate with their markets, causing aggregate freight demand to fall. In the short run, it will be the relative values of these attributes which will determine modal choice; in the long run, however, the absolute values of these attributes will establish modal choice.

Because of the changing nature of freight modal alternatives, an abstract mode framework gives the analyst freedom necessary to assess how new alternatives in the choice set — especially new intermodal combinations — may compete by defining them in terms of their attributes. This allows a methodology to be sufficiently responsive and flexible to long-term changes in the freight transport market in order to generate forecasts which are useful to planners.

5.3 ATTRIBUTES OF CHOICE SET ALTERNATIVES

Each modal alternative in the choice set will be uniquely defined in terms of several attributes, and each decision is based on the perceptions of the values and importance of these attributes. These attributes include all factors which a shipper considers relevant to the modal choice decision. This section describes some of these attributes by defining them and identifying their relevance to the choice process (see Table 5.3).

5.3.1 Door-to-Door Rates

The freight rate is the out-of-pocket compensation paid by the shipper to the carrier to ensure the delivery of the shipment according to shipper-specified service and performance levels. As such, the freight rate directly corresponds to the service level, increasing as service levels improve and decreasing as performance grows worse. The rate also corresponds to the carrier's costs, which correspond to the type and quality of service they provide. Accordingly, there is a trade-off between service quality and economy. For a given commodity, the shipper's modal choice can be viewed as an evaluation of the trade-off between freight rates and service factors:

$$\text{mode choice} = f\left(R, S\right) \tag{5.1}$$

where R = rate-related attributes

S = service-related attributes

For example, the literature has continually found that rail service is cheaper than motor carriers, usually by 15-20 percent, for "identical" service. This difference in rates reflects a perceived difference in service quality between the two modes (see also Ref 87).

Freight rate computation is complicated by the different pricing policies that different carriers for different modes apply and by the presence of contract discounts. For a given mode, the rate will generally be a function of the commodity's characteristics, the shipment size, the distance to be traveled, and the desired service level:

$$R = R\left(k, q, L, S\right) \tag{5.2}$$

where k = commodity attributes,

q = shipment size, and

L = shipment distance.

However, for the same commodity, shipment size, distance, and service level, there may be rate differences between shippers and carriers. These differences can reflect negotiated discounts resulting from contracts and seasonal factors.

5.3.2 Door-to-Door Transit Time

Door-to-door transit time, also referred to as travel time, refers to the amount of time it takes for the shipment to travel from pick-up at the origin to delivery at the destination. Travel time will be affected by personnel, congestion, mileage, network conditions, and interline transfers (Ref 88). Travel time will add to the costs of the shipping firm through equipment depreciation and the commodity's value and perishability.

If two modes are equally reliable in transit time but have differences in speed, why would the faster mode be preferred to the slower mode? First, quicker transit times allow the firm to respond to concerns of seasonality and obsolescence. This is true for agricultural items, such as fruits and vegetables, whose perishability encourages rapid freight. However, this is also true for goods such as apparel, which have no perishability concerns but do have cyclical and short-lived periods of demand.

Second, a shorter transit time enhances the firm's ability to respond to sudden fluctuations in demand, such as a firm needing replacement parts for its manufacturing equipment. The more costly that the equipment's down time is, the more the firm would be willing to pay for accelerated shipments to restart production. Since such demand is rather inelastic with respect to price, a carrier can earn short-run profits from such shipments. They can only do so if their service's transit time is short enough to be able to respond to fluctuations in demand.

Third, longer transit time may lead to issues in equipment availability. For private carriers, fleet and vehicle utilization can be maximized when transit time is improved. For contracted transportation, the carrier has a similar interest in maximizing the productivity of its capital equipment. Such factors have led to the introduction of sleeper cabs for motor carriers, which allows two drivers to serve the same shipment, to reduce the down-time associated with labor.

Moreover, goods in transit are in effect "inventory-on-wheels," analogous with goods in production in a factory. Slower modes are ones which increase in-transit inventory, which adds to production costs. Saleh and Das (Ref 89) provide an illustration of this, demonstrating that quicker yet more unreliable modes of transit would result in lower inventory costs than slower, more reliable modes.

5.3.3 Dependability and Reliability

More than transit time, firms are concerned about dependability and reliability in transit time. Greater uncertainty in transit time leads to the necessity for larger inventory stocks and possible lost sales, resulting in greater holding costs and lesser revenues. This is especially a problem for firms which implement just-in-time inventory management systems (Ref 90).

The attribute of dependability and reliability addresses several questions shippers look for in transportation service. Can the selected mode or carrier be counted upon to make pick-ups and deliveries according to when they promise? Are the carrier's estimates for transit time reliable? If there is a deviation between the actual transit time and the promised transit time, how much of a difference is there? What is the distribution of these differences?

Kullman (Ref 88) proposed several different methods of measuring transit time reliability, based on the standard deviation of transit times, the time by which a certain percentage of loads arrive, the shortest time interval for a given percentage of loads to arrive (which measures the peaking tendency of transit time distribution), the highest percentage of loads arriving in a given time period, the percentage of loads arriving within a certain number of days from a standard, and the average number of days shipments are late. Each of these reflects slightly different interpretations of reliability, according to a firm's specific requirements.

5.3.4 Loss and Damage

Different modes will have different safety risks, resulting both from the amount of shipment handling that occurs between the shipment's origin and destination, and also from the vibration, exposure, and accident risks the shipment will face during carriage. For high-value commodities, such as electronics, loss and damage are a significant consideration and will cause shippers to prefer modes where shipment handling is minimized as is the risk of in-transit damage.

The importance of loss and damage in a modal choice decision can be assessed through identifying insurance and security expenditures associated with each shipment. However, loss and damage are associated with a mode or carrier's reputation as much as any other economic factor. Rail is commonly viewed at a disadvantage compared to motor carrier, because of the possibility of theft at rail yards and the vibration during transit. Recent months, however, have seen an escalation in the hijacking and robbery of trucks in Mexico, with firms losing millions of dollars in cargo and equipment. Motor carriers have been forced to rely on contract security services to reduce losses, resulting in higher transportation costs (Ref 14). At the same time, there has been an increase in train robberies at the border, where merchandise on U.S. trains is stolen and trafficked into Mexico. Officials are still searching for solutions to this problem, as the railroads have little ability to recover the freight (Ref 91). A mode which can promise a high level of commodity security will likely garner a high mode share.

5.3.5 Equipment Availability

For firms which do not provide their own equipment for shipping and carriage, equipment availability and capacity is an important concern. This equipment can include anything from trailers, tractors, boxcars and containers, to carrier-owned loading and unloading equipment, to vehicle drivers and operators. If the appropriate modal equipment is not available, the shipper is forced either to accept a delay in the pick-up or delivery date, or to select another carrier or modal alternative. This shortage of equipment will either result from the carrier's failure to anticipate demand or from longer-than-expected transit times for key pieces of equipment. Historically, this has been more of a problem for railroads than for other modes, although both motor carriers and railroads have reported anecdotal evidence of equipment "disappearing" in Mexico.

Equipment availability, better than any of the other attributes listed, represents the supply of transportation in the freight market, as was shown in section 5.1. Equipment availability is a concern when carriers do not plan appropriately for increases in overall freight demand by increasing their carriage capacity.

To the extent that carriers try to operate less equipment because of the risks of overinvesting in capital, there may be a premium attached to a specific mode; this premium will be reflected in the freight rates. In the short run, equipment shortages may affect how a shipper perceives a carrier or mode. In the presence of shipper-carrier contracts, this will result in some inertia in modal choice. For example, a shortage in boxcars today may cause a shipper to be disinclined toward rail when a new logistics contract is negotiated two years from now, which may result in a shift toward motor carriers at that time. Therefore, the effects of equipment availability on modal choice are often reflected in the rate a carrier charges and in the variability in transit time.

5.3.6 Responsiveness and Flexibility

An unquantifiable but relevant aspect in a firm's modal choice is the carrier's responsiveness and flexibility to meet the shipper's needs. For this attribute, carrier size and scale are important considerations, since larger carriers may be too large to be truly responsive to customer needs. As carriers have seen the need for better customer service in attracting shippers, there has been a greater emphasis on responsiveness through the use of better partnerships between shippers and carriers and through interchanging agreements among modes.

Smaller carriers are perceived to be more responsive, because they can more easily tailor their services to match customers' needs. This has been perceived to favor motor carriers, although the degree of this advantage cannot be assessed. As larger carriers become better equipped for intermodal transportation, their flexibility and responsiveness should improve. Improved tracking and information management systems will help all modes to achieve higher levels of responsiveness to customer needs, perhaps reducing the relative significance of this attribute in the long-run.

5.3.7 Geographic Coverage

Many shippers have cited geographic coverage as an important attribute in modal choice. For contracted transportation services, geographic coverage is especially important in that it will expand the pool of possible suppliers and markets available to the firm.

For trade between the United States and Mexico, the importance of geographic coverage to shippers has manifested itself in the trend toward partnerships with carriers. Many U.S. carriers have negotiated contracts with Mexican transportation providers to allow for interchanging of shipments, giving shippers or forwarders "one-stop shopping" in their search for transportation services. Firms which are starting to tap into new NAFTA export markets will likely gravitate toward firms which have established a solid geographic presence in both countries. The NAFTA environment may lessen the importance of partnerships in developing geographic coverage, although partnerships will still maintain an advantage because they utilize local knowledge on both sides of the border to improve customer service.

5.3.8 Frequency of Service/Waiting Time

If, like most rail and air services, a mode offers prescheduled service, frequency of service may influence modal choice decisions. More frequent service allows a manufacturer greater freedom in scheduling production and deliveries in order to maximize profits. Less frequent service increases a firm's waiting time to receive and send shipments, which could result in extra inventory costs at both ends of the shipment.

It would be difficult, however, to assess the influence of service frequency on modal choice. Its influence will depend largely upon the firm's ability to coordinate its production plan with the carrier's delivery and pick-up schedule. Firms with more frequent inventory turnover would be likely to prefer a transportation service which offers a similar frequency of service, or which is able to respond quickly to demand.

Since not all modes offer prescheduled service, measuring service frequency — or its cost to the shipper — could prove challenging. Waiting time might be used as a substitute, which would reflect the time a shipment is ready for pick-up and when it is actually under the carrier's control. However, this waiting time could be a function not only of poor service frequency, but also of poor inventory management practices on the shipper's part. Manufacturers will often be able to adjust their production schedules according to the service frequency of a chosen mode. Hence, frequency of service is generally not uniquely influential in modal choice.

5.3.9 Special Equipment

As the modal descriptions in section 5.2 indicated, certain modes will require special equipment for usage. For example, a shipper wishing to use container service must be able to load and unload the goods from the container. In addition, the characteristics of the commodity might demand special equipment to preserve its value, such as refrigerated transport for produce.

The need for specialized equipment could be represented in the modal choice decision in one of two ways. It could act to eliminate several modal alternatives from the choice set, since they cannot meet those equipment needs. Alternatively, the need for special equipment could be reflected in changing other attributes of an alternative by raising rates, reducing market coverage, or reducing service frequency.

5.3.10 Perception of Choices

Table 5.2 provides a look at how each mode is commonly perceived relative to other modes in terms of some service attributes and other characteristics. This table should be interpreted with caution, since each attribute depends somewhat on the shipment being considered. One cannot make a simple, generalized assessment of a mode in terms of its attributes independent of considering the shipment's characteristics, such as origin, destination, and shipment size.

Table 5.2 Modal performance for several service attributes

Service Attribute	Motor Carrier	Rail	Air	Maritime
Rates	Moderately high	Low	High	Low
Variable costs	High	Moderately low	High	Low
Fixed costs	Low	Moderately high	High	High
Need for consolidation	Moderately low	Moderately high	Moderately low	High
Ability to transport large volumes	Moderately low	High	Very low	High
Ability to transport small volumes	High	Moderately low	High	Low
Ability to transport bulk cargo	Moderately low	High	Low	Moderately high
Ability to transport palletized cargo	High	Moderate	High	Moderately high
Door-to-door service	High	Moderate	Moderately low	Low
Market coverage	Point-to-point	Terminal-to-terminal	Terminal-to-terminal	Terminal-to-terminal
Number of terminals	High	Moderately high	Moderately low	Low
Degree of competition	High	Moderate	Moderate	Low
Energy efficiency	Low	Moderately high	Low	High
Speed	Moderately high	Moderately low	Very high	Low
Transit time reliability	Moderately high	Moderately low	Medium	Medium
Security	High	Moderately high	High	High
Safety	Moderately high	Moderately high	High	High
Loss and damage	Moderate	High	Low	Moderately low
Availability	High	Moderate	Moderate	Low
Flexibility	High	Medium	Low	Medium

Compiled from: Harper (Ref 92), UNCTAD (Ref 93), LBJ School (Ref 94), Walton (Ref 95)

An important omission from Table 5.2 is intermodal transport. This omission occurs because intermodal cannot be characterized as a homogeneous mode, since it depends on which modal alternatives are linked, how they are linked, and the efficiency of intermodal transfer(s). Each intermodal option would need to be examined individually.

5.4 CHOICE EVALUATION

The modal choice decision is made by invoking a decision rule to evaluate each alternative according to its attributes. This section describes the type of decision rule which is most often applied in freight modal choice, and how the rule considers the attributes which were described earlier.

5.4.1 Decision Rules

There are two classes of choice rules: noncompensatory and compensatory rules. Noncompensatory rules do not allow for trade-offs on attributes for a given option, while compensatory rules do allow for trade-offs, so that exceptional performance on one attribute can compensate for inferior performance on another attribute.

The simplest of noncompensatory rules would be to select a choice which maximizes or minimizes the "most important" attribute. Only if there is a tie between alternatives in the most important attribute would the shipper examine other attributes. Other noncompensatory rules involve conjunctive and disjunctive rules, lexicographic rules, or elimination by aspects. While simple to understand, noncompensatory rules do not reflect survey data which indicate that shippers view modal choice as a multicriteria optimization problem.

Compensatory rules, on the other hand, allow for trade-offs among all important attributes of each transportation alternative. There are two major subsets of compensatory rules: utility maximization and bounded rationality. Utility maximization is rooted in consumer theory, which states that shippers will purchase transportation services to maximize their utility, given an income constraint. Each shipper assesses the utility associated with each alternative based on its attributes and selects the alternative which maximizes utility. Utility maximization assumes that decisionmakers behave rationally and consistently in response to perfect information regarding each of the attributes of all alternatives.

Bounded rationality, on the other hand, assumes that decisionmakers have limited perceptions, imperfect information, and information gathering and processing constraints. Individuals will be rational within constraints, using a "satisficing" decision rule, by which a certain minimum number of criteria are met. The shipper's behavior "is rational within the limits of his cognitive and learning capacities and within the constraint of limited information" (Ref 96).

Surveys have indicated that the decisionmaking process in modal choice has historically followed a bounded rationality character (Ref 97), where the gathering and processing of information is considered to be a costly activity. A survey conducted by Chow and Poist (Ref 98) found that many of the factors which shippers considered important in modal choice were either recorded informally or not at all. Bruning and Lynagh (Ref 99) reported from a survey that "more respondents indicated that their firms employed subjective as opposed to objective quantitative evaluation techniques." Respondents commented that distributors are not convinced that objective techniques were useful. In an earlier survey by Saleh and LaLonde (Ref 100), 43 percent of the U.S. traffic executives surveyed reported either agreeing or strongly agreeing to the statement that not all available alternatives would be known to the decisionmaker. Moreover, 52 percent of the traffic executives interviewed made modal choice decisions "instantaneously," which would not reflect a careful, well-researched decisionmaking process.

The age of these surveys suggests that there may be a greater emphasis now on a rational search process. The increased competition resulting from deregulated transportation services increases both the costs and benefits of information gathering. Accordingly, it is likely that utility maximization under an assumption of bounded rationality will be the driving force behind shippers' modal choice decisions.

5.4.2 Ranking of Attributes

Many surveys have been undertaken to identify which attributes are most important to shippers in modal choice. These studies differ in geographic scope, market coverage, sample population, attributes included, attribute definitions, ranking systems, survey methodology, and economic environment. The results of 23 such studies are summarized in Appendix B. The differences in labels and definitions used by study authors hide some similarities in the most important factors in modal choice. The attributes which were most frequently mentioned as among the five most important attributes in the modal choice decision are listed in Table 5.3. Only three attributes — reliability, transit time, and freight rate — were considered to be among the most important modal attributes on a majority of the surveys. Several other attributes were named in lesser frequency, indicating the presence of differences in survey designs and samples.

Table 5.3 Significant modal attributes in shippers' modal choice decisions

Attribute	**# of times mentioned**
Reliability and dependability	26
Door-to-door transit time	16
Door-to-door rates	12
Loss and damage	8
Equipment availability	8
Shipment tracing and information	6
Customer service quality	5
Responsiveness and flexibility	5
Geographic coverage	3
Past experience with carrier	3
Special equipment	3
Billing and order accuracy	2
Carrier's financial stability	2
Frequency of service	2
Willingness to negotiate rates	2
Other	12

Source: Appendix B.

It is important to note that shippers' and carriers' perceptions of which attributes are most important in modal choice may differ. Three studies which surveyed shippers and carriers separately are summarized in Table 5.4. These studies found varying degrees of correspondence between shipper and carrier perceptions. Evans and Southard (Ref 101) found that their preferences were remarkably similar; Foster and Strasser (Ref 102) found some areas of difference between shippers and carriers, while Abshire and Premeaux (Ref 103) found numerous differences between shippers and carriers. Since Evans and Southard collected data during times of regulation for both domestic railroad and motor carrier service, more attention will be paid to the two more recent studies.

Foster and Strasser found some similarity between carriers' and shippers' preferences, if for no other reason than the smaller number of factors — eleven — that were examined by the authors. The authors attributed the difference in ordering to a failure of carrier agents to be rewarded by their supervisors for performance which they consider important in carrier and modal selection. Likewise, shippers are not rewarded for performance which will develop long-term relationships with carriers. Abshire and Premeaux examined a larger set of selection criteria than Foster and Strasser, using 35 service-related criteria and a larger sample size. However, Abshire and Premeaux's criteria included many more subjective factors than the set used by Foster and Strasser, which may not be clearly or easily perceived by carriers.

Table 5.4 Differences in perceptions of attributes in modal choice

Authors	**Shippers' top five**	**Carriers' top five**	**Key factor deviations**[i]
Evans and Southard (1974)	Dependability of service Total transit time Carrier's ability to trace quickly Past performance of carrier Loss and damage experience with carrier	Dependability of service Total transit time Carrier's reputation for dependability Carrier's reputation for quality Carrier's knowledge of shipper's needs	Carrier honors shipper's routing requests Carrier salesmen make regular calls *Nearness of carrier offices to the shipper* Courtesy of vehicle operators
Foster and Strasser (1990)	Schedule reliability Willingness to negotiate service Willingness to negotiate rates Door-to-door rates Door-to-door transit time	Door-to-door transit time Door-to-door rates Schedule reliability Willingness to negotiate rates Willingness to negotiate service	*Willingness to negotiate service* Door-to-door transit time Door-to-door rates
Abshire and Premeaux (1991)	Reliability of on-time delivery Reliability of on-time pick-up (tie) Door-to-door transit time (tie) Carrier response in emergency situations Carrier's financial stability	Reliability of on-time delivery Reliability of on-time pick-up Carrier's reputation for dependability (tie) Carrier's cooperation with shipper personnel (tie) Carrier's knowledge of shipper's needs	Courtesy of vehicle operators *Carrier's leadership in offering more flexible rates* Freight damage experience with the carrier Carrier's knowledge of shipper's needs Carrier's cooperation with shipper personnel Carrier's reputation for dependability Past performance with the carrier *Carrier response in emergency situations*

Source: Evans and Southard (Ref 101), Foster and Strasser (Ref 102), Abshire and Premeaux (Ref 103)
Please refer to Table B-1 for descriptions of each study. Nonitalics and *italics* indicate that the factor was considered more important to the carrier and shipper, respectively.

[i] For Evans and Southard, these factors had mean rankings that had a statistically significant difference between carriers and shippers at a level of confidence of 0.05. For Foster and Strasser, these factors had differences in their mean rankings of at least 1.0. For Abshire and Premeaux, these factors had (1) mean rankings that had a statistically significant difference between carriers and shippers at a level of confidence of 0.01, and (2) a ranking of at least 4.0 with either the shippers or carriers.

The difference in perceptions between carriers and shippers calls attention to the significant role that freight forwarders play in freight movement across the Texas-Mexico border. Of the 23 studies examined in Appendix B, only one — that undertaken by Murphy, Daley, and Dalenberg (Ref 104) — focused its survey on international freight forwarders. Respondents' top five concerns were, in order, equipment availability, shipment information, loss and damage, convenient pick-up and delivery times, and freight rates. While transit time reliability and transit time were not listed among the five most important factors, the first three attributes in order of importance act as controls for the freight forwarder to ensure the reliability of an estimated transit time. This affirms the findings of the three studies highlighted in Table 5.4, which indicate the importance of reliability in transit time to both shippers and carriers.

5.5 METHODOLOGICAL INTEGRATION

The purpose of the modal choice model step in the forecasting methodology is to predict modal choice given information about shipment and commodity characteristics. This model is based on a disaggregate decision made by an individual firm regarding the modal choice for an individual shipment. As Figure 5.3 shows, the development of this disaggregate model will be used to predict aggregate modal choice.

In developing this model for freight movements across the Texas-Mexico border, several results from this chapter stand out. First, many modal alternatives are available, with growth in intermodal expanding that choice set. This would encourage the use of an abstract mode approach in order to model mode choice. Second, modal choice decisionmakers consider the trade-offs between numerous attributes in order to select a freight mode. Accordingly, the modal choice model must be able to reflect which attributes decisionmakers consider to be relevant, and how these attributes compare with each other in importance. Finally, modal choice for 60 percent of shipments across the Texas-Mexico border is determined by a third party; therefore, it is important to discern what influences the modal choice decisions made by freight forwarders.

These results are incorporated in the specification and calibration of the modal choice model. The model consists of a utility function specified for each modal alternative for each commodity group. Modal alternatives will be defined according to an abstract mode framework, in order to allow for the development and improvement of modal alternatives over time. Models are specified by defining a set of commodity and shipment attributes which are considered influential in the modal choice decision. The model is calibrated using a set of disaggregate modal choice observations containing values for each of the specified attributes. These observations, since they reflect revealed modal preferences, represent the criteria which shippers, carriers, and freight forwarders consider important in determining modal choice. The calibrated model would be used to predict modal shares for each commodity group, based on "average" shipment characteristics for each shipment group.

The use of a disaggregate model to predict modal choice over an aggregate population creates a potential problem in that modal choice decisions and shipment characteristics, such as shipment size, are often interdependent. For this reason, there is a step following the calibration of the modal choice model allowing the modal choice model to be stratified according to shipment size. For those commodities where modal choice and shipment size are sensitive to each other, shipment sizes can be grouped into blocks, such that there is a modal choice gradient within a block. Each block would then have its own modal choice model specified.

The predictive accuracy of this model depends primarily on two elements: the specification of the modal choice model, and the quality of the calibrating data sample. Each of these will be discussed in Chapter 7.

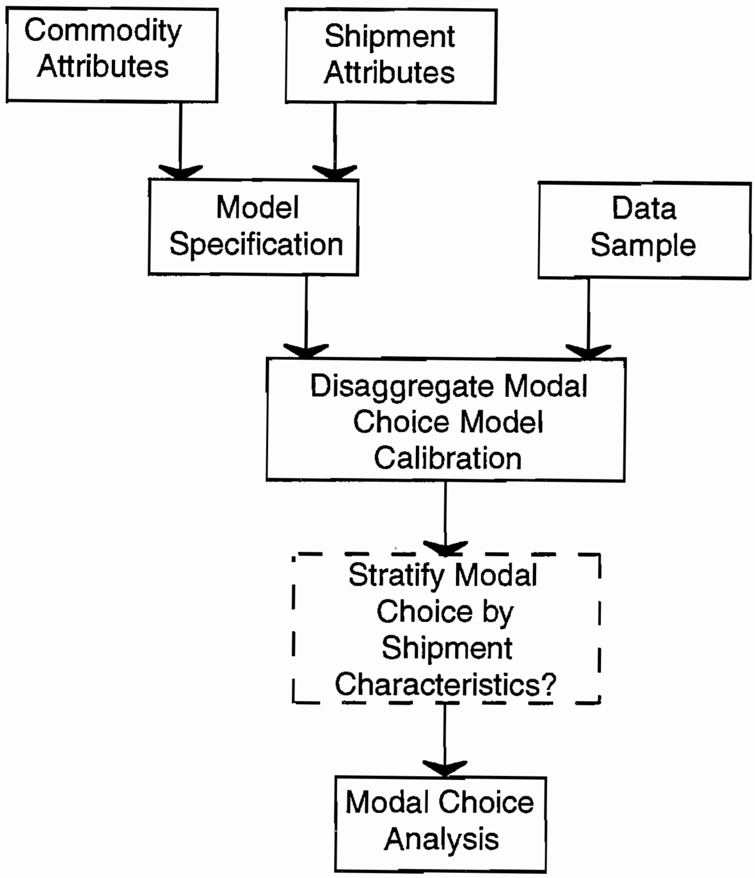


Figure 5.3 Components of modal choice analysis

5.6 SUMMARY

This chapter described and defined the modal choice decision which a firm confronts. Included in this examination were considerations of the decisionmaker, the choice set, the attributes of choice set alternatives, and a discussion of decision rules for evaluating modal choices. The dependence of modal choice on commodity, shipment, and modal attributes means that it is best modeled as a disaggregate choice, based on individual shipments. The freight forecasting methodology developed in this report consequently incorporates a disaggregate element in order to better predict modal choice. These predictions will lead to more accurate predictions of the transportation impacts of NAFTA in the Texas-Mexico border region.

CHAPTER 6. INVENTORY THEORY AND SHIPMENT SIZE

The previous two chapters described a procedure for estimating the expected flows of commodities between regions and determining the modes by which these commodities travel. The transportation impact of NAFTA, however, is not necessarily directly proportional to the value of freight crossing the border. Rather, it relates to the number and weight of vehicles which cross the border. The damage to pavement and railroad tracks increases disproportionately to increases in shipment size. Accordingly, it is important to consider how firms make shipment size decisions in addition to modal choice decisions.

Therefore, the third step in this report's methodology is to determine how each mode's traffic will be distributed into vehicle trips. This decision is dictated by the selection of a shipment size, which is generally done in accordance with production requirements and inventory costs. Instead of focusing on just the transportation aspect of the firm's decision-making process, this chapter examines how a firm's inventory strategies will affect and be affected by the firm's choice of transportation strategy. This is done in the context of logistics costs and how these relate to various inventory strategies. From this analysis, the discussion proceeds to an examination of the relationship between shipment size and ordering frequency, and how this relationship affects the final distribution of freight.

6.1 LOGISTICS

Because it is more of a short-run decision than other decisions made by the firm, the selection of a transportation strategy may be determined by optimization of the transportation sub-problem. However, transportation costs can be considered to be a production cost similar to any other outlays a firm must make. Potential or actual transportation costs will have a feedback effect on higher level decisions in the decision hierarchy. Consequently, one must consider how a transportation strategy fits in with the firm's other objectives.

It is important to recognize that a firm's overall objectives will be based on maximizing profit, which are a function of the firm's overall revenues and its generalized cost of production. This production cost may be defined by the following function:

$$C = C\left(Y, w_K, w_L, w_M, w_T, w_I\right) \tag{6.1}$$

where C = cost of production

Y = output

w_α = factor price of input α (where $\alpha = K$ [capital], L [labor], M [materials], T [transportation], I [inventory & storage])

According to this function, transportation is an input which may be substituted for some inputs and substituted by others. From the decision hierarchy discussed in section 3.3, this long-run substitutability is apparent. It is also apparent that transportation is unique in that it is the final stage in the production process, a stage that can be treated distinctly from the rest of the process (Ref 32). Because transportation decisions can be made at different levels in the decision hierarchy, it is important to consider how these decisions will interact with each other. For this reason, it is helpful to view the transportation problem as a logistics problem — a problem integrating transportation into the firm's operational framework.

Logistics has perhaps as many definitions as there are practitioners. One author said that logistics' role is concerned with everything about inventory, transportation, information, packaging, and service-level decisions (Ref 75). Another has defined logistics costs as the difference between the factor price of transportation and the freight rate of transportation (Ref 46). Logistics cost has been defined as including transportation, inventory, warehousing, order processing, and documentation/packaging costs (Ref 76). Hastings (Ref 105) characterized logistics as merely a new term for total supply chain management.

In general, a logistics system has two principal elements: the choice of types and locations of physical facilities, and the choice of an inventory and transportation system to service and supply the facilities (Ref 88). From the decision hierarchy discussed in Section 3.3, the choice for facility construction and location is a more capital-intensive, long-term decision than is the choice of inventory and transportation systems. Therefore, in the context of the problem of determining modal choice and shipment size, a logistics strategy will be defined to include only the costs of selecting a particular transportation option.

The emphasis on the logistics perspective over the more limited transportation perspective is relatively recent. It comes primarily as a result of increasing emphasis on customer service and a greater concern for tighter inventory control. Moreover, the focus on logistics reflects the realization of the interdependency of each division of a firm's operations on the others, and how this interdependency can be exploited to reduce costs and improve efficiency for the firm.

Total logistics cost can be expressed as the following:

$$\begin{pmatrix} \text{total} \\ \text{logistics} \\ \text{cost} \end{pmatrix} = \begin{pmatrix} \text{transport} \\ \text{costs} \end{pmatrix} + \begin{pmatrix} \text{stationary} \\ \text{inventory} \\ \text{costs} \end{pmatrix} + \begin{pmatrix} \text{in - transit} \\ \text{inventory} \\ \text{costs} \end{pmatrix} + \begin{pmatrix} \text{expected} \\ \text{stock - out} \\ \text{costs} \end{pmatrix} \tag{6.2}$$

The distinction between stationary inventory costs and in-transit inventory costs reflects the position of the shipment in the supply chain. Before the shipment can be used in production, the cost of product maintenance is called in-transit inventory costs. These costs include the costs of capital tied up with the shipment, depreciation, and loss and damage costs. Stationary inventory costs depend on the amount of stock on hand, the commodity's density, its perishability, and its value. All inventory costs will be a function of the value of the product. Consequently, logistics costs will increase as the value of traffic increases.

Based only on the preceding considerations, it would be desirable to minimize inventory as much as transportation considerations will allow. However, a depleted inventory can result in significant costs to a firm, such as surcharges for backordering, reliance on secondary (more expensive) product sources, shutdown in production processes, and, ultimately, lost product demand. All of these factors are incorporated into the final term in equation 6.2, expected stock-out costs. These costs will be based on the frequency of stock-outs, and the expected cost to the firm per stock-out.

6.2 INVENTORY AND STOCK-OUT COSTS

Integral to the discussion of logistics is the role of inventory in the production process. The carrying of inventory allows firms greater ability to use larger and more infrequent shipments, which would reduce the number of vehicles associated with freight traffic while handling the same volume of cargo. On the other hand, a lack of inventory and warehousing will direct a firm toward smaller vehicles and shipment sizes, with more frequent shipments.

Kullman (Ref 88) defined an inventory system as "a set of linkages between the customer, retailer, wholesaler, and producer." The inventory system includes the location and size of product storage, as well as the type of storage (i.e., in production, in transit, in warehousing, etc.) and how it is managed. According to Tersine (Ref 106), an inventory system can serve four basic functions: to reduce lead time in meeting demand, to allow the firm to treat various dependent operations in an independent and economical manner, to provide a cushion for the firm to handle uncertainty in demand or supply, and to allow a firm to seize the advantages of economies in order size or batch size.

The quantity of inventory in a system will be defined by the amount of stock available for immediate use and the safety stock. Safety stock serves as a buffer against uncertainty in either the demand or supply of stock to a firm. This uncertainty can result from deviations from demand forecasts, fluctuations in supply usage, or variability in travel time (Ref 107). Safety stock helps to absorb shocks in supply and demand, preventing the absence of stock (also known as a stock-out) which may result in an interruption in production for manufacturers or in lost sales for retail shippers.

The effects of stock-out conditions are to significantly reduce both short-run and long-run market shares (Ref 108). A stock-out can be avoided by expediting shipments, such as by using air freight. However, such services have a significant premium in cost. Blumenfeld, Hall, and Jordan (Ref 107) illustrated that a small safety stock inventory would reduce the likelihood of stock-out conditions, reducing the expediting costs substantially.

Given uncertainty and the stochastic performance of production and transportation systems, a safety stock level cannot be defined which will absolutely provide a guarantee a zero probability of a stock-out occurring. The logistics manager is required to set a safety stock level according to a certain service criterion. Possible criteria that have been used include: the length of stock-out (days), the number of items out of stock (items), the length of stock-out weighed by the number of items short (item x days), or the percentage probability of a stock-out (Ref 88). The amount of safety stock does not have to correlate with the amount of stock which is used per ordering period.

In fact, Zinn and Marmorstein (Ref 109) found that determining safety stock levels according to variance in demand forecast errors results in a savings over levels determined by variance in demand, while maintaining the same service level.

To illustrate how inventory systems integrate into the overall production and distribution strategy of a firm, descriptions of three basic classes of inventory management systems are provided. These systems, which have undergone a great deal of scrutiny in the logistics literature, include the perpetual inventory system, the periodic inventory system, and the "just-in-time" (JIT) inventory system. For the purpose of this discussion, it is assumed that the inventory in question is a homogeneous good with negligible perishability in quality or in value over time.

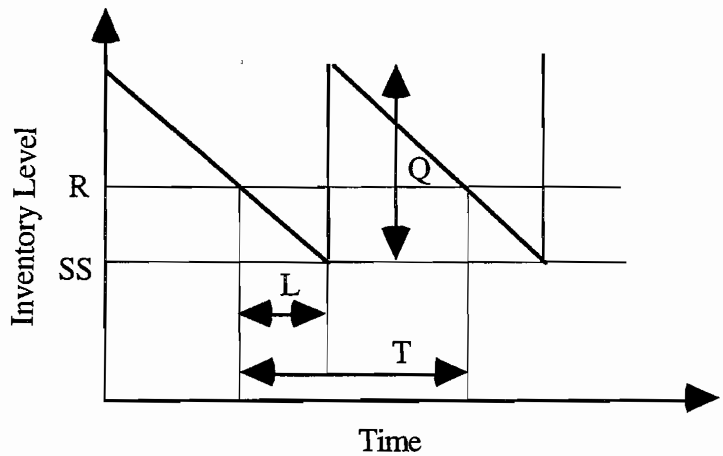
Perpetual Inventory System: As the name implies, a perpetual inventory system (also known as the fixed reorder point method) is an inventory management strategy in which the inventory level of an input is continuously monitored. A new shipment is ordered whenever the inventory level reaches a prespecified reorder point.

Assume that a firm has a constant rate of usage of an item that is stocked in its inventory. Figure 6.1 shows how the item's stock level might vary as a function of time when a perpetual inventory system is in place at a manufacturing plant. The stock level will fall as production is in process, until it reaches the reorder point, *R*. An order of size *Q* will be placed at the reorder point, but the stock is not immediately replenished. The time between shipments (*T*) will be determined by the usage rate. This diagram assumes that there is some transit time or lead time (*L*) between the supplier and the plant. Consequently, the reorder point must be positioned above the safety stock level (*SS*). To avoid a stock-out, the plant must use no more than *R* units of stock during the transit time. Accordingly, *Q* may be defined as:

$$Q = I_0 - I + DDLT \tag{6.3}$$

where I_0 = desired stock level
I = actual inventory level
$DDLT$ = demand during lead time, L

The firm will set an inventory level which will minimize the plant's costs by selecting an optimal Q_0 to minimize total inventory costs. Because the perpetual inventory system assumes that production and shipment rates are both deterministic, Q_0 can be directly solved using one of two methods: economic order quantity (EOQ) and economic production quantity (EPQ). EOQ assumes that there are no economies of scale involved in either storage or in ordering. Annual total inventory costs are defined as follows:



L=Lead time
Q=Shipment size
R=Reorder point
SS=Safety stock level
T=Time between orders

Figure 6.1 Perpetual inventory system method (adapted from Kullman, Ref 88)

$$TC = R \times P + \frac{R \times C}{Q} + \frac{Q \times H}{2} \tag{6.4}$$

where TC = annual total inventory costs (\$ / yr)

R = annual demand (units / yr)

P = purchase cost (\$ / unit)

C = order cost (\$ / order)

Q = shipment size (units / order)

H = capital carrying cost (\$ / unit · yr); often expressed as $H = i \times P$, where i is a percentage incorporating the cost of capital, insurance, maintenance, and other inventory costs

At the quantity where inventory costs are minimized, the following is true:

$$\frac{d(TC)}{dQ} = 0 \tag{6.5}$$

Solving equation 6.5 yields the inventory cost-minimizing quantity, Q_0:

$$Q_0 = \sqrt{\frac{2C \times R}{H}} \tag{6.6}$$

The EPQ model assumes that inventory is added into production gradually, while production is in-process. The total inventory cost equation differs from 6.4 by including rates of production and demand:

$$TC = R \times P + \frac{R \times C}{Q} + \frac{Q(p - r)H}{2p} \tag{6.7}$$

where p = production rate

r = demand rate

Because the full shipment size is not transferred into inventory, these inventory costs are less than those associated with the EOQ model. Accordingly, the optimal shipment size to minimize *TC* is:

$$Q_0 = \sqrt{\frac{2C \times R \times p}{H(p - r)}} \tag{6.8}$$

The EPQ model offers a more favorable cost than the EOQ model. However, its applicability is limited either to inventory movements within a production facility, or to transportation shipments which have the characteristic of constant input rates, such as bulk or pipeline shipments.

It is important to recognize that the optimal shipment size is determined independent of vehicle capacity or contractual requirements. Contractual requirements may specify that the time between consecutive shipments must be less than T* time units. Consequently, the selected shipment size for a perpetual inventory system would be:

$$Q = \min \left(u, R \times T^*, Q^0\right) \tag{6.9}$$

where u = vehicle capacity

Since the perpetual inventory system requires real-time information regarding stock levels, it is best suited for inventoried commodities with either low usage rates or low value (Ref 88).

Periodic Inventory System: The periodic inventory system, or fixed reorder period method, involves cyclical surveys of stock levels and orders accordingly. There are two principal advantages of this system over the perpetual inventory system. First, in the absence of automatically monitored inventory levels, a perpetual inventory system is not practicable. Second, employing the periodic inventory system will result in regularly scheduled shipments which may result in cost savings (Ref 77).

Optimization rules for finding an optimal review period T are more difficult for the periodic inventory system, especially if there is any variability in usage rates. Q will be defined in the same manner as it was for the perpetual inventory system, based on the difference between current and desired stock levels and on *DDLT*. Because the optimization determines nothing about feasibility for Q, Q may fall below minimum shipment size requirements for certain modes. This problem will not significantly increase costs, however, as the total cost is rather insensitive to shipment size when Q is greater than the optimal EOQ (Ref 110). Moreover, the safety stock level must protect against stock-outs over a period of $T+L$ days, since the stock level may fall below R at any time after an inventory review.

Just-in-Time System: The objective of just-in-time (JIT) inventory systems is to acquire, transport, and manufacture the necessary items just in time for their consumption, in order to minimize inventory costs (Ref 111). Developed by Japanese car manufacturers in the 1970s, JIT has become increasingly common in manufacturing in the United States. A 1988 study found that 90 percent of manufacturers and distributors surveyed considered JIT to have at least some strategic importance (Ref 112). Another survey in the same year of 200 U.S. companies found that 70 percent of companies had implemented or were in the process of implementing JIT in purchasing, production, and distribution (Ref 113). Improvements in information technologies have allowed more firms to implement JIT in their operations, and the associated cost savings, confirmed in a survey by Lieb and Miller (Ref 114), have encouraged them to do so.

The development and implementation of JIT is primarily intended to counter the expense of inventory holding and maintenance. JIT theory assumes that an increase in transportation costs, in order to generate quicker and more reliable service, will be more than offset by a savings in inventory costs, thus providing a net savings to the firm. On an annual basis, $1 of inventory can cost perhaps 25 cents annually to carry (based on 15-16 cents of interest, and 9-10 cents for ordering, shipping, receiving, storage, and insurance costs). Successful JIT implementation is claimed to provide firms many benefits, such as lower scrap costs, lower inventory carrying costs, higher quality, quicker response to engineering design changes, improved administrative efficiency, greater productivity, and reduced inventories (Ref 115).

Compared to other inventory systems, a JIT system places greater emphasis on partnerships; efficiency in materials handling; upstream-oriented modal choice decision-making; a reliance on fewer, more local suppliers; and a more stringent set of transportation requirements. In terms of transportation, JIT implementation results in an increase in shipment frequency, a decrease in shipment size, and an increased emphasis on reliability in pick-up and delivery. As one author put it, "a controlled transportation system with short transit times and absolute dependability of service capable of making several deliveries a day is essential to an effective JIT system" (Ref 116). The importance of dependability in shipments reinforces the need for close partnerships between shippers and carriers: 73 percent of JIT users have specific contracts with carriers regarding their JIT service (Ref 117). There is also an increased emphasis on consolidation and the use of smaller shipments (Refs 112, 115).

Most authors agree that these transportation characteristics would tend to make motor carriers the preferred mode for JIT organizations. In a survey of traffic and logistics managers, Lieb and Miller (Ref 114) reported that rail market share dropped among companies using JIT, while motor carrier and air gained market share. As air freight becomes more accessible to manufacturers, it will start to replace motor carriers for some JIT shipments (Ref 113). Higginson and Bookbinder (Ref 118) contend that rail can be competitive with motor carriers on JIT shipments, arguing that TOFC intermodal movements could be used instead of LTL motor carriers for smaller shipments.

While JIT's transportation requirements are not unique to inventory management, their importance is greater — especially since stock-out conditions are still to be avoided. Bagchi, Raghunathan, and Bardi (Ref 111) found that the use of JIT does not significantly alter the relative importance of factors in carrier selection; however, JIT organizations generally appeared to be more concerned about carrier selection factors than those organizations who did not use JIT.

JIT is not applicable to all firms and commodities. It is most successful for products with high volumes of demand that can be produced with repetitive manufacturing techniques (Ref 113).

The introduction of JIT systems and the growing emphasis of total quality management in production has led to a decline in inventory levels. One author found that the ratio of the value of inventory to sales fell from 1.87 in 1980 to 1.54 six years later, when JIT systems became "fashionable" in U.S. manufacturing. Over the same period the ratio of inventory to gross national product in the U.S. fell from 18.37 to 14.82 (Ref 117). Part of the reduction in standing inventory is a reflection of the ability of information technology to help manufacturers manage inventory levels more efficiently. However, much of that also comes from a widespread interest and application of JIT and related inventory management systems.

6.3 INVENTORY-THEORETIC MODELS

Many interactions exist between modal choice and inventory management decisions. For example, variability in transit time could lead to different reorder points, and differences in transportation costs could lead to differences in shipment sizes or order quantities. The presence of these interactions resulted in a series of modal choice predictive models called inventory-theoretic models which seek to capture the interactions between these decisions.

The principle behind the inventory-theoretic model is that modal choice and shipment size decisions cannot be considered independently. For this reason, one views a firm's modal choice decisions in the context of its inventory management policies, as a part of its overall strategy to minimize logistics costs. Any modal attributes which are theorized to influence modal choice (e.g., speed, reliability, and flexibility) must be expressed as costs in order to have an impact in the model.

The first inventory-theoretic model for freight demand was proposed by Baumol and Vinod (Ref 45). The model relies on abstract modes and commodities, such that each modal alternative and each commodity is described by its attributes. Modal attributes which would highly influence inventory and shipment size decisions include shipping cost per unit (including rates, insurance, etc.), mean transit time, variability in transit time, and carrying cost per unit of transit time. Commodity characteristics which are relevant include point-to-point rates charged by carriers, storage cost after delivery, the cost of delivery delays in terms of lost sales and other disadvantages, as well as product value. The model is based on the EOQ framework (equation 6.4), with an adjustment made in order to consider the probability of stock-out by including safety stock. Safety stock is defined by:

$$SS = k\left(\left(s+t\right)T\right)^{1/2} \tag{6.10}$$

where SS = safety stock

k = proportionality constant

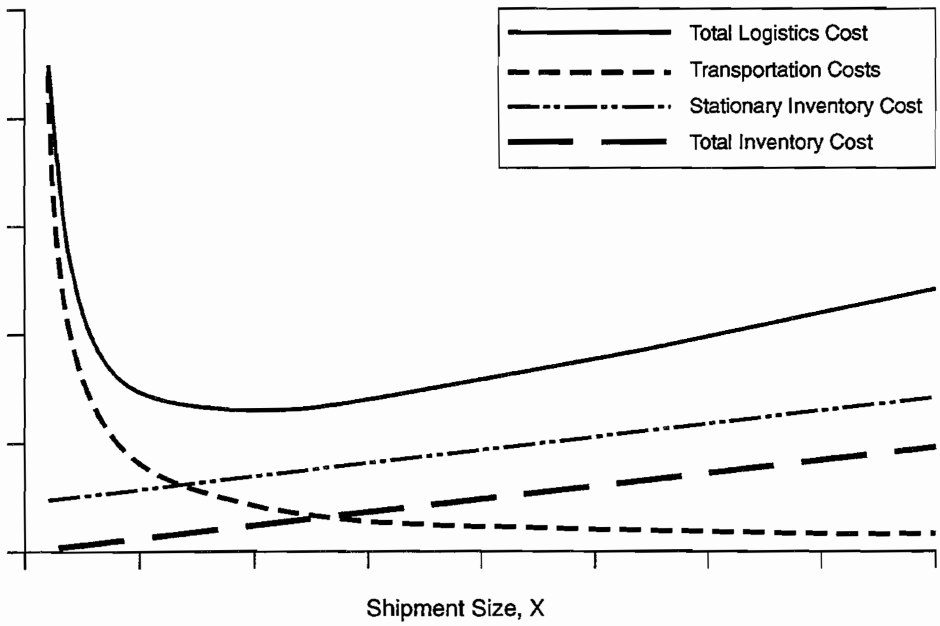
s = average time between shipments (years)

t = average transit time (years)

T = total amount transported per year

Since Baumol and Vinod's seminal work, the inventory-theoretic model has been generalized in numerous directions. Das (Ref 119) extended the model to allow for shipment size and safety stock to be determined independently. Allen (Ref 23) took Baumol and Vinod's work further by incorporating a firm's total cost function — including transportation — to determine an optimal total output size. Given this output, an optimal shipment size would be selected according to EOQ considerations. Constable and Whybark (Ref 120) incorporated the effects of stochastic lead-time demand in their inventory theoretic approach. They proposed a two-step heuristic optimization. First, for a given modal alternative, shipment size and reorder levels were to be selected to minimize cost. Then, the cost-optimal values for quantities were tested for other modal alternatives to identify the cheapest solution. Their heuristic risked the possibility of accepting nonexact, suboptimal solutions, but the cost savings was outweighed by the gain in computational efficiency. Tyworth, Rao, and Stenger (Ref 121) developed a multimodal model to estimate for a given shipment size Q, service level P_z, and replenishment level s, the expected total annual logistics costs (ETALC) for a transportation option. They proposed a three-stage process for determining the optimal transportation strategy. First, for each transportation option, s is calculated such that P_z is achieved over a range of shipment sizes. Second, over a range of values of Q, values for ETALC as a function of s and P_z are explicitly enumerated. Finally, the ETALC curve is analyzed to find the lowest cost option. Tersine, Larson, and Barman (Ref 122) and Abdelwahab and Sargious (Ref 62) considered the interdependence of shipment size and modal choice, the former through the use of freight rate discounts and the latter through modeling modal choice and shipment frequency (or shipment size) in a joint choice model.

As this discussion implies, the inventory-theoretic model is necessarily a firm-level model. It is most applicable for firms to determine optimal shipment sizes according to their unique cost characteristics. Because it requires firm-level information about costs and revenues, the inventory-theoretic model cannot be easily used as a forecasting tool. However, it does help to elucidate the link between modal choice and inventory decisions. First, there is a clear trade-off between inventory and transportation costs, as is shown in Figure 6.2. Larger shipment sizes, which would result in unit savings in transportation costs, require larger inventory costs (Ref 110). Conversely, smaller shipment sizes result in reduced inventory costs and higher shipping costs.



Assumes transportation cost is fixed per shipment. Adapted from Ref 110.

Figure 6.2 Logistics cost as a function of shipment size

Second, transit time is considered important by shippers on the basis of its effect on inventory decisions. One would note from Figure 6.2 that in-transit inventory costs — the difference between total inventory costs and stationary inventory costs — is a constant. The in-transit inventory cost will be proportional to the transit time and value of the good; consequently, a quicker transit time would reduce logistics costs for any range of shipment size. From equation 6.10, it is clear that safety stock requirements — and consequently logistics costs — would be significantly affected both by shipment frequency and transit time. Quicker, more frequent shipments (i.e. lower values of s and t) are obviously advantageous, which explains the savings in logistics costs that firms find in adopting JIT systems.

Finally, some shipment sizes will never be optimal. Unit logistics costs can often be improved either by shipping more frequently with more consolidation (i.e., by switching from TL to LTL), or by shipping less frequently with less consolidation (i.e., by switching from LTL to

TL). The optimal carriage method will depend on both the customers' production rate and inventory holding costs (Ref 123).

6.4 METHODOLOGICAL INTEGRATION

The inventory-theoretic model confirms the observation from Section 3.3 that modal choice and shipment size are both short-run decisions. The model explicitly examines the trade-offs between these decisions according to firm-level cost and production functions. Since the modal choice process developed in Chapter 5 is not disaggregate, neither can this step in the methodology. Consequently, an alternative to the inventory-theoretic approach must be developed, in order to acknowledge the interdependence of modal choice and shipment size decisions in a way that is compatible with the methodology developed in this report.

Figure 6.3 outlines a procedure for integrating shipment size decisions into the methodology which incorporates survey data as well as the shipment data used to calibrate the modal choice model in Chapter 5. The process is more exploratory than explanatory in nature; it seeks to examine what shipment size decisions firms have made, and to identify how these decisions relate to any inventory policy.

The first element involved in this process is to examine the data sample to identify how shipment size relates to commodity attributes. For example, would the weight of a shipment indicate that it is sufficient for a vehicle load? If the shipment falls below a maximum weight limit, would the commodity density or shipment value indicate that it would be classified as a full vehicle load? Does average shipment size depend upon which mode is chosen? For each commodity within each commodity group, what is the distribution of shipment sizes? A commodity which is observed to have a wide variance in shipment sizes would likely have significant inventory costs. Consequently, modal choice and shipment size decisions for such a commodity are more likely to be strongly interdependent.

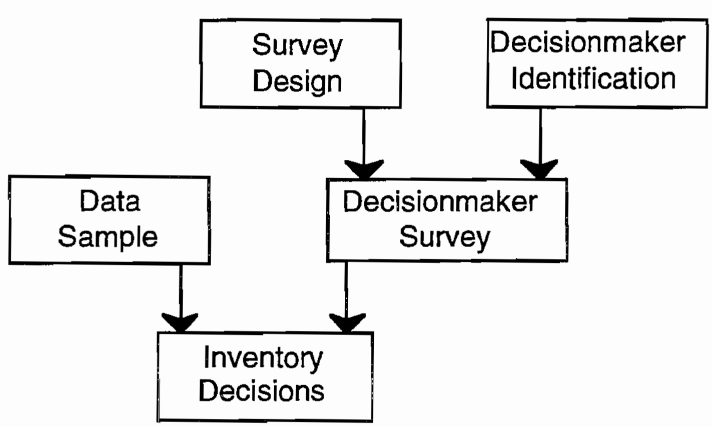


Figure 6.3 Components of inventory decision analysis

The second element in this process involves a survey of shippers to determine the inventory management practices of firms. This will provide new information for the methodology because it will better examine the presence of JIT. Firms employing JIT will have more frequent shipments than those who do not, but the data sample may not adequately represent these firms. Therefore, the survey will seek to identify those firms which use JIT or similar inventory systems. To implement the survey requires developing a survey design and identifying the population to be sampled. Chapter 7 will discuss each of these issues in greater detail.

The result of this stage will be a series of mathematical procedures by which the estimates for commodity flow for each mode can be converted into estimates for vehicle trips. This is the closing step in the methodology, which will enable forecasts for trade between the U.S. and Mexico to be converted into vehicle trips to assess the transportation impact of such trade.

6.5 SUMMARY

This chapter analyzed interactions between inventory and transportation decisions in the context of a firm's logistics strategy. Different inventory strategies will require different transportation options. As firms increasingly adopt JIT systems in their inventory management, transportation services have to be quicker and more reliable. It is clear that shipment size will not be determined independently of considerations about a firm's inventory policy and stock levels.

CHAPTER 7. DATA AND IMPLEMENTATION ISSUES

Chapters 4, 5, and 6 described three components that comprise a methodology to forecast freight transportation flows between Texas and Mexico. This chapter reviews this methodology and describes how it should be implemented. The review consists of a catalog of the different steps of analysis which are required in order to generate estimates for freight demand across the Texas-Mexico border. Next, the data requirements of the methodology are discussed. Following this is a description of issues relating to implementing this methodology. This will lead to conclusions identifying areas for future research.

7.1 METHODOLOGY

The previous three chapters discussed the three separate components comprising a methodology to forecast freight demand between Texas and Mexico. First, the input-output method is used, with interregional and dynamic enhancements, to provide estimates for the commodity flows between industries and regions. Second, a modal choice model is developed for each commodity group, based on transportation, shipment, and commodity attributes. Third, firm surveys and shipment size data are used to develop a profile of how firms determine shipment size. These results are combined to estimate the vehicle flows associated with trade across the Texas-Mexico border, as is shown in Figure 7.1.

Economic Analysis: The purpose of this step, introduced in Chapter 4, is to quantify the economic interrelationships between sectors and regions within a system including the United States and Mexico. This is performed applying a dynamic, interregional input-output method to the economy of the region. The function of the method centers on the creation and manipulation of the transaction matrix. Developing the transaction matrix involves two steps: first, specifying the number and nature of commodity groups which are included in the matrix; and second, determining values for x_{ij} for the value of freight shipped from commodity group i to commodity group j. This matrix is modified to account for elements of dynamic change, including technological change, geographical shifts in industry, and growth in new and emerging industries.

The first step in developing the transaction matrix is to classify productive economic activity within the U.S.-Mexico system into n commodity groups. This classification of commodities into groups must be mutually exclusive and collectively exhaustive, such that every commodity belongs to one and only one commodity group. Commodities within each group should have similar functional roles within the economy and, if possible, similar transportation-related characteristics as well. The initial matrix is completed by determining the value of goods transferred between each pair of commodity groups m and n for each pair of regions i and j, x_{mn}^{ij}. This will constitute an initial, interregional transaction matrix.

In order to use the input-output matrix as a forecasting tool, the transaction matrix must be altered to be dynamically sensitive. Survey data collected from representative firms within each commodity group will help to determine the rate and direction in which productive activity is changing. According to equations 4.4, 4.5, and 4.6, this requires the specification of B and A', the incremental and best technology matrices. The second part of the economic analysis, then, is to incorporate these matrices in updating X. B and A' are not associated with a specific time horizon; therefore, an analyst could develop alternative scenarios for how B and A' would change over the twenty-year forecast horizon, generating several intermediate updates of X before arriving at a final X' matrix.

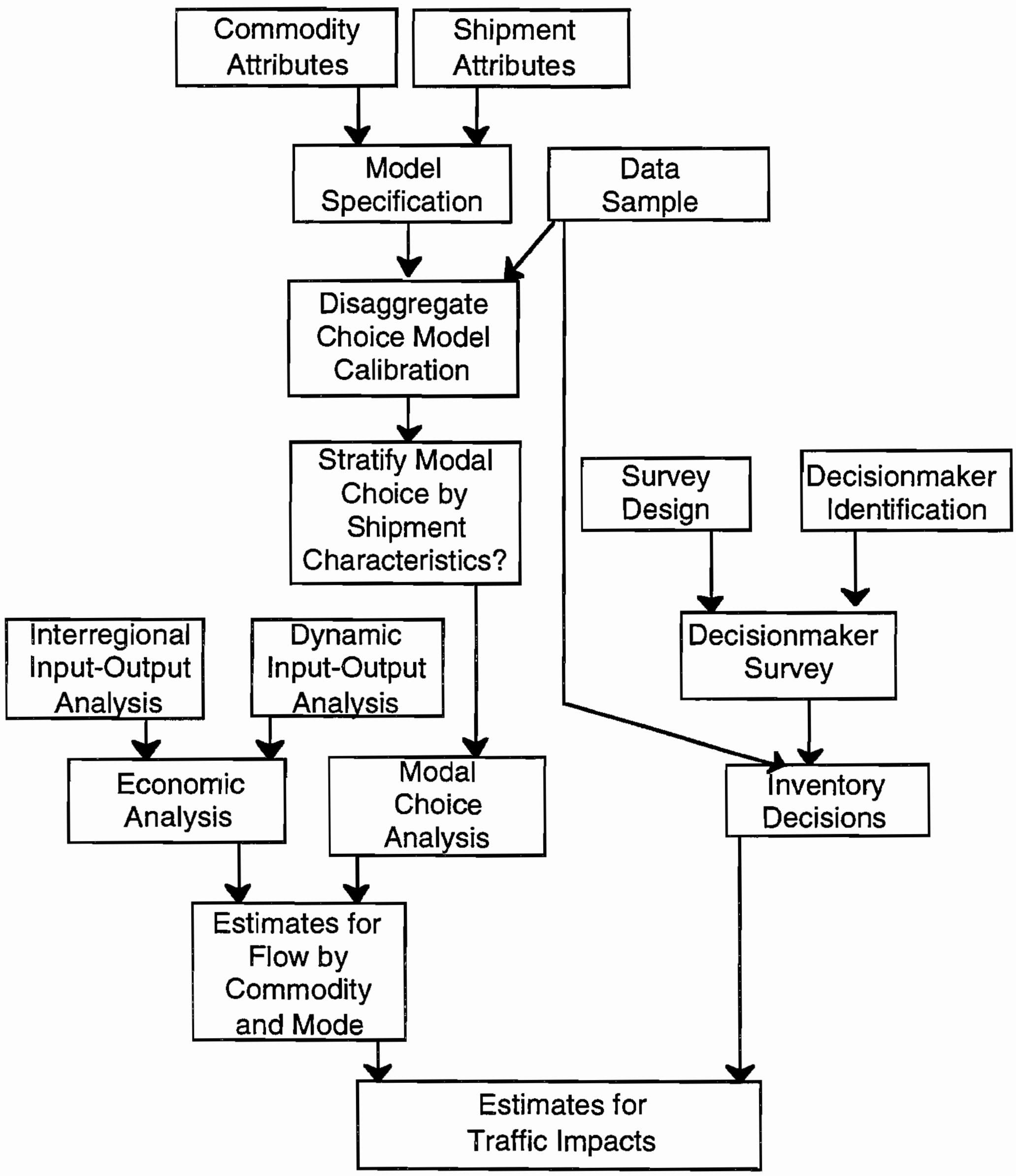


Figure 7.1 Detailed methodology for forecasting freight demand

The completion of the economic analysis step will result in forecasts for the value of freight for each commodity group *m* moving between regions *i* and *j*:

$$\sum_{n} x'^{ij}_{mn} = x'^{ij}_{m} \tag{7.1}$$

Modal Choice Analysis: The focal point of this step is the specification and calibration of disaggregate predictive modal choice models. Models will be calibrated for individual commodity groups since modal choice depends upon the attributes of the commodity being shipped. In order to improve the predictive accuracy of the model, each commodity group may be further sub-divided into individual commodities according to their transportation-related characteristics.

Since modal choice decisions are modeled according to random utility theory, each mode *k*'s utility in shipping commodity *m* consists of systematic and random components, v_{km} and ε_{km}. For a multinomial logit model, the probability of selecting mode *k* from choice set C_m will be an extension of equation 2.10:

$$P_m(k) = \frac{e^{v_{km}}}{\sum_{k \in Cm} e^{v_{km}}} \tag{7.2}$$

To specify a modal choice model, a functional form must be selected for the utility associated with each modal choice, i.e., v_{ijkm}. Some sample forms are shown in Table 7.1. Each functional form specifies that a modal alternative's utility is a function of *V* shipment or transportation attributes and *W* commodity attributes. These attributes can relate to the characteristics of a commodity within a commodity group (e.g., density, value), the attributes of a specific modal alternative (e.g., speed, reliability), or the attributes of the shipment (e.g., shipment size, distance).

The model must be calibrated in order to determine values for the modal parameters α and β. Model calibration will require the synthesis of a set of modal choice observations for specific shipments providing a thorough representation of each separate commodity within each commodity group.

As was discussed with inventory-theoretic models in Chapter 6, modal choice is often made in conjunction with decisions regarding shipment attributes. For this reason, the exact same commodity may often be carried by different modes depending on the shipment size or distance. For certain commodities, the importance of shipment attributes in determining modal choice will require that models be developed for blocks within each commodity group according to shipment attributes, such as distance or weight. Blocks should be continually subdivided as long as the β coefficients for shipment attributes are found to be statistically significant during the calibration process.

Table 7.1 Functional forms for modal choice utility function

Additive: $$v_{ijkm} = \alpha_o^{km} + \sum_W M_w^m \alpha_w^k + \sum_V K_v^{ijkm} \beta_v^{ijkm}$$

Translog: $$v_{ijkm} = \ln\left(\alpha_o^{km} \prod_W \alpha_w^{k\,M_w^m} \prod_V \beta_v^{ijkm\,K_v^{ijkm}}\right)$$

$$v_{ijkm} = \alpha_o^{km} + \sum_W M_w^m \ln \alpha_w^k + \sum_V K_v^{ijkm} \ln \beta_v^{ijkm}$$

Logarithmic: $$v_{ijkm} = \alpha_o^{km} \prod_W \alpha_w^{k\,M_w^m} \prod_V \beta_v^{ijkm\,K_v^{ijkm}}$$

$$\ln v_{ijkm} = \alpha_o'^{km} + \sum_W M_w^m \ln \alpha_w^k + \sum_V K_v^{ijkm} \ln \beta_v^{ijkm}$$

where α_w^{km} = coefficient for commodity attribute w for commodity m on mode k

M_w^m = value of commodity attribute w for commodity m

β_v^{ijkm} = coefficient for shipment or transportation attribute v for commodity m on mode k from region i to region j

K_v^{ijkm} = value of shipment or transportation attribute v for commodity m on mode k from region i to region j

The modal choice analysis step results in a set of utility functions for each block within each commodity. The number of utility functions corresponds to the number of modal alternatives which are specified. The set of modal alternatives possible for a commodity m, C_m, must be narrowly defined, for the use of abstract modes tends to distort modal shares as the number of modal alternatives increases. These utility functions, when substituted into equation 7.2, will provide estimates for the likelihood of selecting a specific transportation alternative according to commodity and modal attributes.

Estimates for Flows by Commodity and Mode: Combining these first two steps produces estimates for the value of each commodity transported by each mode. The principle behind this step is that one can estimate a modal share for each block within each commodity group. This is done by developing a set of mean shipment characteristics and identifying $P_m(k)$ for each mode k. Assuming that the commodity mix within each commodity group M will not change over time, one can multiply the mode share for each commodity m by the proportion of the commodity group's shipments which the commodity represents, and sum it up over all commodities:

$$P_M(k) = \sum_m P_m(k) \times \frac{X_m}{X_M} \tag{7.3}$$

where

$P_M(k)$ = the share of commodity group M's freight transported by mode k

X_m = the amount of commodity m shipped per year (\$ / year)

X_M = the amount of commodity group M shipped per year (\$ / year)

This will produce estimates for the amount of freight in each commodity group moving by each mode:

$$P_M(k) \times X_M = \left(\begin{array}{c} \text{the amount of commodity} \\ \text{group } M \text{ transported} \\ \text{by mode } k \text{ (\$ / year)} \end{array} \right) \tag{7.4}$$

Since the intent of the methodology is to analyze transborder flows, X_m and X_M should only represent those flows which are likely to cross the Texas-Mexico land border.

Inventory Decisions: This step will determine the number of vehicles it will take to move the quantities derived in equation 7.4. Shipment size will fall between defined parameters based on modal capacity and inventory and production requirements, as is shown in Table 7.2. The definition of modal options in the second step will place maximum limits on expected vehicle capacity for each mode. This shipment size would create a lower limit for the number of vehicle trips associated with a volume of travel. From this point, the firm's inventory strategy will determine how many trips are required to move the freight.

Table 7.2 Constraints on shipment size

Minimum	Constraint	Maximum
Receiver's minimum shipment size requirement, according to ordering costs and production processing	**Inventory & production**	Determined by receiver's inventory strategy, available storage space
Sufficient to meet minimum weight requirements (if any)	**Vehicle capacity**	Maximum weight requirements for transport vehicle

As was described in Section 6.4, two elements are involved in this step. First, the data sample used to calibrate the modal choice model is examined to see how shipment size relates to commodity attributes. Some commodities will not have sufficient demand to justify a full vehicle load, while others do not have a high enough density to reach a maximum weight limit, even if the vehicle is full. For each commodity there will be a range of shipment sizes which are transported. This range reflects the types of demand patterns associated with each commodity.

As this range widens, the variance in the number of vehicle trips resulting from a given volume of freight will increase. The variance results from the types of assumptions which are made regarding future inventory and production strategies employed by firms. To minimize this variance, it is important to be able to assess how shippers currently manage their inventory, and how this might change over the planning horizon. This is addressed in the second step, where shippers are surveyed to identify how firms manage their inventory. Just-in-time (JIT) inventory strategies will justify smaller shipments than other inventory management strategies would due to the desire to lower stock levels. Consequently, as JIT usage increases, the number of vehicle trips across the border might be expected to increase. More generally, an in-depth analysis of the supply-side of carrier fleet management strategies would go a long way in providing better predictive capability for this step.

The shipment data and survey responses, synthesized for each commodity group, will help to indicate whether the range of shipment sizes Q_m^k observed in the present will change over the forecast horizon. This range should be adjusted according to any foreseeable industry-wide adjustments in inventory management or adjustments in limits on maximum vehicle loads. After this adjustment of Q_m^k to $Q_m'^k$, the number of vehicle trips for each mode *k* and commodity *m* is:

$$\begin{pmatrix} \text{vehicle trips for} \\ \text{mode } k \text{ and} \\ \text{commodity } m \end{pmatrix} = \sum_{q \in Q} \frac{X_{mq}^k}{q} \qquad (7.5)$$

where X_{mq}^k = value of commodity *m* shipped on mode *k* of shipment size *q*

Estimates of Traffic Impacts: The total border impact of NAFTA will be the sum of the vehicle trips for each mode *k* over all origin-destination pairs which involve a border crossing and all commodities:

$$V_k = \sum_{i,j} \sum_{m} \sum_{q \in Q} \frac{X^k_{mq}}{q} \tag{7.6}$$

where V_k = the number of vehicle trips on mode k across the Texas-Mexico border

7.2 DATA REQUIREMENTS

The forecasting capabilities of this methodology will be constrained primarily by the cost and availability of data. This section will identify the methodology's data needs, highlighting those areas in which data acquisition may prove to be especially expensive or difficult.

7.2.1 Economic Analysis

The input-output method requires the development of a transaction matrix, with values x_{mn} for the amount of industry *m*'s products which are purchased by industry *n* per year. When the method is extended interregionally, these x_{mn} values must be determined between each pair of regions *i* and *j*. When the method is further enhanced to permit dynamic change, data is required to define both the best technology matrix, A', and the degree to which industries have improved to reach it, *B*. Each of these aspects are discussed.

Transactions Matrix: The principal drawback to the input-output method is its data requirements for developing *X*. For *n* commodity groups, n^2 different x_{mn} values are required. One method to gather this data is to use descriptive statistics collected and aggregated previously by government agencies. This data would be comparatively inexpensive to maintain, and likely would have a high degree of accuracy. The problem with this method is that the industrial classification scheme used in these statistics may not be consistent with the methodology. In other words, the data may not be sufficiently disaggregate to account for differences in commodity characteristics which would significantly impact modal choice decisions.

An alternative to this method would be to survey firms from each industry to determine from what industries they purchase and to which industries they sell. These firms must be selected to be both quantitatively and qualitatively representative of their industry; i.e., these firms, or firms of similar size, should comprise a significant share of the market, and the production methods and cost structures at these firms should be similar to those used in the industry as a whole. Sales and purchasing data would need to be collected from a variety of firm sizes in each industry, in order to reflect any capacity or scale economy issues in the technological coefficients.

Interregional Analysis: Applying the pure interregional model, as recommended in section 4.3, requires an *X* matrix to be created between each pair of regions in the system. For a system with *r* regions, this increases the cost of gathering data through survey methods by a factor of r^2.

The use of governmental data for this purpose, however, may introduce two problems. First, the use of different industrial classification systems in data collected by the United States and Mexico may increase the difficulty of identifying interrelationships between economic sectors.

Second, there is no guarantee that a set of regions defined in the data will be a set of regions which would be useful in predicting traffic across the Texas-Mexico border. However, government data may be available to indicate interrelationships between smaller geographical units, such as states or regions, within each nation. Such data would improve the accuracy of the transaction matrix and should be used if available.

Dynamic Analysis: Chapter 4 identified three separate dynamic effects which may complicate a freight forecast: change in production methods, the long-run mobility of factors of production, and the emergence and growth of new industries. The simplest of these is to assess the effects of changes in production methods. To do this is to determine how the incremental coefficients, B, are chosen. Carter (Ref 71) suggested five methods which may be used: analyzing the evolution of coefficients over time through an industrial time-series analysis; measuring the coefficients of new manufacturing plants as estimates of best practice; looking at average new plant coefficients as estimates applicable to expansions of older plants; inferring estimates of incremental coefficients from data on older establishments; and comparing indirectly inferred incremental coefficients with new plant coefficients. Each of these methods requires a firm-level analysis in order to determine appropriate values for B, which could prove to be an excessively costly proposition for a relatively disaggregate matrix. Differences in factor prices will result in different "best" technologies for different regions. Accordingly, surveys would need to be undertaken within each subregion to find the best technological mix for each industry in each region.

It is considerably more difficult to gather data which can incorporate the effects of the mobility of factors of production. If one views "older plants" as the former spatially optimal location of plants and "newer plants" as the new optimal location of plants, then the techniques proposed by Carter are tenable in the short run. Firms will not adjust their long-run decisions over plant and market location simultaneously; rather, the movement of firms will tend to be diffusive in nature, according to the time horizons each firm uses for such decisions.

It is not clear, however, how these short run trends will develop in the long run. One possibility is that the movement of capital will be quickest at the beginning of the forecast horizon, as firms are eager to seize immediate advantage of the opportunities NAFTA provides. Alternatively, the high sunk costs involved in new capital investments would initially encourage firms to act tentatively in order to minimize risk in an uncertain economic environment. The development of new and emerging industries will be similarly difficult to forecast. These industries combine both significant changes in production technology and difficult-to-forecast industrial growth patterns.

Since it is impossible to collect data about future activities, it is recommended that Carter's assumptions are held. Government statistics and/or survey statistics may be used to assemble this data.

7.2.2 Modal Choice Analysis

The primary goal of data collected for the modal choice model is to calibrate a prespecified model to make it consistent with observed freight movement patterns between the U.S. and

Mexico. To calibrate the modal choice model, three types of data will be necessary: commodity attributes, modal attributes, and shipment data. Some of these attributes are listed in Table 7.3.

Many disaggregate models have already developed catalogs of commodity attributes. Models developed at MIT in the 1970s — such as Kullman (Ref 88) and Chiang (Ref 46) — defined commodities according to characteristics identified in a 1975 MIT commodity study. Such a study would need to be updated to reflect the introduction of new commodities and changes in the costs of carrying capital.

Table 7.3 Factors influencing modal choice decisions

Commodity Attributes	Modal Attributes	Shipment Data
Commodity density	Equipment availability	Average shipment size
Fragility	Packaging and handling	Average shipment value
Perishability	Modal access	Average length of haul
Temperature sensitivity	Geographic coverage	
Inventory and storage costs	Transit time (a.k.a. speed)	
	Transit time reliability	
	Freight rates	

Shipment data and modal attributes need to be provided on a shipment-level basis. The first four modal attributes listed in Table 7.3 are largely based on shippers' perceptions, while the last three reflect "measurable" quantities based on actual shipment data. Most sets of shipment-level data will, at best, only have estimates for expected transit time, but usually do not indicate the actual transit time. Moreover, transit time reliability — considered vitally important by most shippers — is either not measured at all or is measured internally by firms for their own record-keeping purposes. Freight rates are often a function of commodity attributes as well as length of haul and shipment size, and will be affected by rate discounts which are differentially applied across shippers. The average values for shipment size, shipment value, and length of haul will be readily identifiable from shipment-level data. Inclusion of these variables implies, however, that modal choice is strictly dependent on these values, rather than influencing these values. Therefore, if any relationship is found between modal choice and either shipment size, value or distance, the commodity group should be subdivided into blocks according to the dependent variable.

When values for any of these attributes is missing for a major component of the data, the analyst may apply subjective judgment to generate values for missing observations. Out of the feasible modes, one mode k' should be selected as a reference mode, with other attribute values expressed as ratios according to this reference value. For example, if all values are missing for K_q^{ijkm}, then let

$$K_q^{ijk'm} = 1 \tag{7.7}$$

and
$$\overline{K}_q^{ijkm} = \frac{K_q^{ijkm}}{K_q^{ijk'm}} \tag{7.8}$$

where $\overline{K}_q^{ijkm}$ = value for K_q^{ijkm}, scaled with respect to k''

Therefore, if the transit time of one mode is twenty percent faster than another mode's for the same commodity on the same corridor, it would have $\overline{K}_q^{ijkm} = 0.8$. Observations which have measurements could be easily converted to ratio-based values through applying equation 7.8.

To assess the effects of subjective criteria on modal choice, the analyst must survey shippers to obtain their perceptions of these criteria. These responses must be quantified for inclusion in the model calibration. Table 7.4 demonstrates a method for translating the subjective responses into numerical values. Because shippers contacted in this survey cannot be matched up with modal choice decisions, these responses should be used to generate "average" values of modal perceptions for each commodity on each *i-j* pair.

Table 7.4 Evaluating subjective criteria for modal choice

Criterion Label	Survey Question	Scale of Response
Equipment availability	To what degree is the proper equipment available on a regular basis to move the commodity by this mode?	100 = Full Availability, 0 = No Availability
Packaging and handling	To what extent is specialized packaging or handling required to use this modal choice to move this commodity between these locations?	0 = No Special Needs (increasing positive integers as requirements increase)
Modal access	Can this mode service this origin and destination for this commodity?	1 = Full Access, 0 = No Access
Geographic coverage	Does this mode offer sufficient geographic coverage and access to allow this commodity to move by this mode?	1 = Full Coverage, 0 = No Coverage

7.2.3 *Inventory Decisions*

This step requires two types of data: shipment data and survey responses. The shipment data collected for calibrating the modal choice model can also be used to provide information regarding the range of shipment sizes associated with each commodity. However, the survey data regarding inventory practices must be assembled from scratch.

The first step in the survey is to compile a list of questions which are appropriate to determining inventory practices. These questions should also provide sufficient identifying information about the firm, such that the analyst can ensure that the survey responses include a broad representation of firm sizes within each commodity group. The following information might be elicited in this survey:

- *Firm attributes:* Value of annual sales by commodity output
- *Supplier attributes:* Number of suppliers; annual value of freight supplied by commodity; number of incoming shipments by commodity

- *Market attributes:* Annual value of freight shipped by commodity; number of shipments by commodity
- *Inventory management:* Is JIT either in place or in the process of implementation?
- The survey distribution should ensure that the sample includes purchasers and suppliers representing all commodity groups and all firm sizes within each commodity group. It becomes clear from Figure 7.2 that the omission of one commodity group from the sample population on either end will have disastrous effects on the survey results when one supposes that one industry, Industry 3, employs JIT inventory management. Consequently, according to Chapter 6, its incoming shipments will be smaller and more frequent. If Industry 3 is not included in the survey, shipment size will be overestimated; if Industry 3 is included and other industries are underrepresented, then shipment size will be underestimated.

7.3 IMPLEMENTATION ISSUES

Several issues must be addressed prior to implementing this methodology as a tool to forecast freight demand across the Texas-Mexico border. This section two of these issues: the sensitivity of the methodology to changes over the forecast horizon, and the way in which interdependent decisions are represented.

7.3.1 Methodology Sensitivity

The use of a twenty-year planning horizon permits an array of factors to alter the pattern of trade between Texas and Mexico over the forecast period. These factors are listed in Table 7.5. The table affirms that the methodology incorporates many but not all changes which will occur over the forecast horizon.

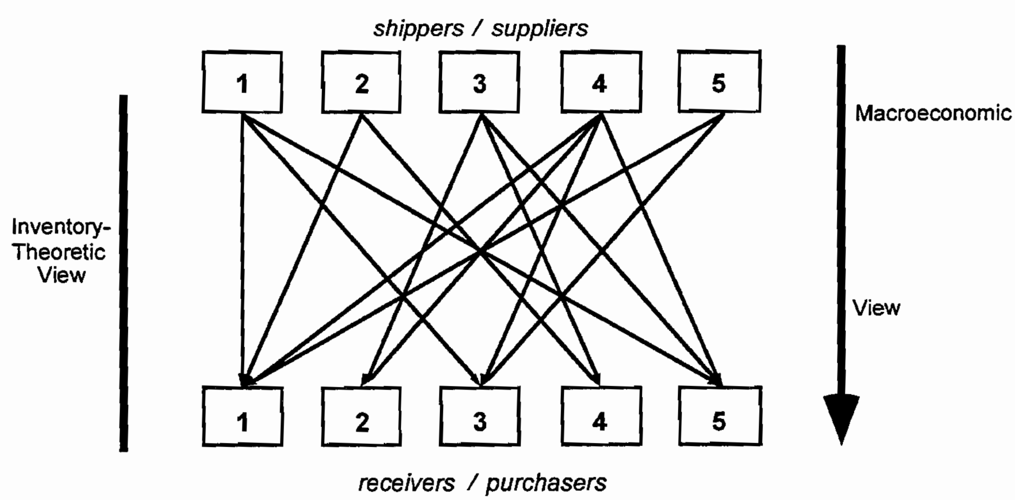


Figure 7.2 Comparison of modeling perspectives

Of those factors listed in Table 7.5, the exchange rate is perhaps the most important variable influencing the character of trade between the two nations. Both the volume of trade between the United States and Mexico and the character of trade — shown by the proliferation of maquiladoras in the mid 1980s — are indicative of the strong linkage between exchange rates and trade. The methodology, while capable of considering the effects of the exchange rate, is not capable of dynamically modeling or predicting the consequences of fluctuations in the exchange rate. For this reason, technological coefficients should be generated for multiple scenarios regarding the exchange rate between the two nations. These will help to establish a confidence interval for estimates of the trade-related traffic impact at the border.

The effects of the "political" factors in Table 7.5 is certainly significant as well. It is difficult, however, to foresee a finite, definable set of scenarios which could represent these political factors, and to identify the consequences of these scenarios. For example, if the process of NAFTA implementation is slowed down or stopped, then previously observed changes in industrial behavior could not be predicted to be replicated over the planning horizon. Because there is no historical data which can be used to complete a dynamic economic analysis, the methodology will be insensitive to such political changes over the planning horizon.

Table 7.5 Sources of change in trade patterns between Texas and Mexico

Economic	Political	Transportation	Industrial	Geographical
Change in the exchange rate	Instability in national governments	*Technological improvement in modal alternatives*	*Changes in production methods*	*Long-term relocation of firms due to NAFTA*
Economic climate: Recession or prosperity	Change in investment patterns in infrastructure	*Improvements in efficiency in border crossings*	*Development and growth of new industries*	Long-term relocation of markets due to NAFTA
Increase in demand due to NAFTA	Introduction of trade agreements with other nations		*Technological innovation*	
	Rescindment of NAFTA		*Changes in inventory management strategies*	
	Expansion of NAFTA			
	Restructuring of NAFTA terms			

Factors in *italics* have been explicitly addressed in the methodology.

7.3.2 Interdependence

The methodology treats economic conditions, modal choice and shipment size as independent; in reality, however, these elements are highly interdependent. The patterns of origins and destinations of freight, for example, will reflect the degree and quality of transportation provision between points. Freight pricing schedules result in different optimal shipment sizes for different modes, with these optimal shipment sizes changing according to production and inventory concerns. The region's economic condition and transportation network, the structure of the freight transportation industry, and many other factors create a dynamic process in which each element impacts the others.

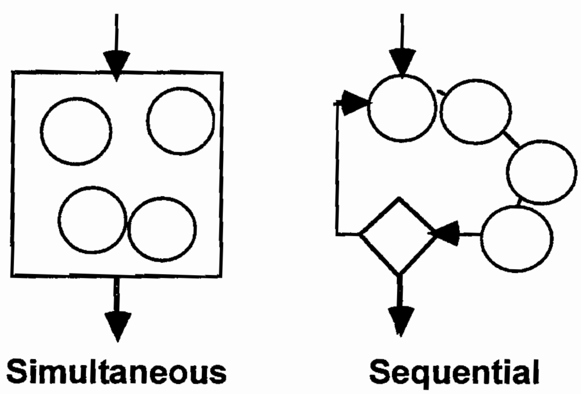


Figure 7.3 Simultaneous and sequential treatments

Theoretically, there are two ways in which a solution incorporating these interactions may be reached: simultaneously or sequentially. These two methods are graphically depicted in Figure 7.3. A simultaneous solution requires concurrent consideration of all factors influencing trade, in the context of an optimization problem. Each actor in the system would make all decisions in a way to explicitly maximize their utility. This utility maximization for shippers and carriers would be a function of current profits, expected profits, expected risk, and other factors. For governmental agencies which have a role in infrastructure provision and maintenance, the utility maximization would reflect a balancing of all fiscal priorities, not just those relating to transportation. A properly specified simultaneous solution would yield appropriate and reasonable estimates for the freight impacts of NAFTA. However, the development of a properly specified model would require information about the utility functions of hundreds and thousands of distinct actors within the system. The amount of data and computations required in such a solution framework is tremendous.

A sequential approach will develop the solution by processing a series of phases which are followed in a predetermined order. Each phase is processed by applying a set of assumptions regarding the other phases. After all phases have been completed, a transient solution is reached.

This solution is tested to see if the assumptions for each phase are consistent with the generated solution. If the assumptions do not hold, the analyst must re-examine phases by updating the assumptions according to the results of the solution. This process iterates until the resulting solution converges with the assumptions. While computationally simpler than the simultaneous framework, the sequential method does not guarantee an optimal solution. There may be several distinct solutions for which convergence is achieved, some of which are not globally optimal.

The methodology developed in this report treats the component steps as sequential and independent. In only one case are two elements explicitly considered to be interdependent: modal choice and shipment size decisions. The methodology structures the two decisions sequentially by dividing them into distinct phases in the framework. In the event that a commodity's modal choice depends upon shipment size, separate modal choice models are developed for each shipment size block. This treatment reflects that these decisions are often made simultaneously.

There are several assumptions implicit in the methodology which will affect the resulting solution. For example, the developed assumption assumes that the freight transport industry is sufficiently competitive such that price does not change as demand increases. However, an "optimal" solution may require an expansion of system capacity which would require shipping prices to increase. Some assumptions which may require re-assessment include: constant congestion effects on freight travel times, constant economies of scale in production or transportation, and the impact of new and emerging industries. Moreover, the solution needs to be examined to ensure that predicted freight movement values do not violate the constraints summarized in Table 7.6. This would suggest that the methodology needs to applied sequentially until a "reasonable," converging solution is achieved.

Table 7.6 Constraints on amount of freight demanded

Minimum	Constraint	Maximum
(none)	**Production capacity**	Maximum amount shipper can produce at given supply price
Private transport: Freight movement must be adequate to offset fleet maintenance costs	**Equipment availability**	Private or common transport: Freight movement must not exceed available fleet capacity
Common transport: Negotiated minimum	**Contractual obligations**	Common transport: Negotiated maximum
(None)	**Network capacity**	Network will not experience abnormal congestion at either nodes or links
Quantity such that cost of transport is less than the difference in market prices between regions	**Spatial equilibrium**	Quantity such that cost of transport is greater than the difference in market prices between regions
Quantity at which supply cost (transportation + production) equals demand price	**Market demand**	Quantity at which supply cost equals demand price

7.4 DIRECTIONS FOR FURTHER RESEARCH

Before this methodology is applied to developing freight forecasts for the Texas-Mexico border, two additional areas of research should be explored in order to maximize the accuracy of any realized transportation forecasts. First, an inventory of available data sources should be compiled. Second, an effort should be made to improve the assessment of the relationship between the number of shipments and the number of vehicles used to transport these shipments.

Inventory of Data Sources: This report made no assessment of the availability of data which may help to fulfill the requirements outlined in Section 7.2. Consequently, one direction for further research would be to assess the availability of data which would aid in the implementation of this methodology. An inventory should be compiled of all existing, available data sources relating to trade and freight movement across the Texas-Mexico border. This inventory should focus on the availability of disaggregate shipment data, as well as on any sales and purchases figures which would be helpful in developing a transaction matrix.

Relationship Between Shipments and Vehicles: There is not a clear relationship between the number of shipments which cross the border and the number of vehicles which are used to transport those shipments. For example, a single "shipment" of steel may be transported via multiple railroad cars, while a less-than-truckload (LTL) carrier may ship hundreds of shipments in a single vehicle-load. This relationship is partially explained by identifying the size of a shipment, but more needs to be said about the effects of consolidation on freight traffic volumes.

For an LTL carrier, effective consolidation is essential to maximizing profits. Each truck shipment has specific fixed costs involved with the hiring of a driver and the depreciation of vehicle capital. The marginal cost of adding weight to each truck is low, consisting of marginally greater fuel consumption and accelerated vehicle maintenance. Until the vehicle exceeds legal weight limits, it is to the carrier's advantage to add shipments to the vehicle in order to reduce average shipment costs.

This report proposes that the number of vehicles be estimated by examining the shipment size patterns associated with each commodity shipped across the border. An alternative method would be to assume that all vehicles across the border will meet the maximum weight restrictions. Therefore, the number of vehicles associated with a given volume of freight could be ascertained by dividing the total volume of freight by vehicle capacity. This would require that the amount of freight estimated in the economic analysis be converted into a weight.

A better understanding of inventory management and shipment consolidation techniques would allow forecasts of freight traffic to more accurately represent true vehicle flows. Further research should consist of examining inventory management practices among firms importing shipments across the border and interviewing carriers to learn more about shipment consolidation techniques.

7.5 SUMMARY

The need for infrastructure investment in the border region, along with forecasts for growth in trade as a result of the North American Free Trade Agreement (NAFTA), has created the need for a comprehensive freight forecasting model. This methodology is designed to improve upon previous efforts by considering how NAFTA would alter the economic environment in which firms operate and the decisions these firms make regarding modal choice and shipment size. This methodology employs three steps in order to develop long-term estimates of future freight-related traffic across the border: an economic analysis of the region, calibration of modal choice models, and an assessment of inventory practices.

This report recommends that this methodology be applied to forecast the demand for freight transportation across the Texas-Mexico border. This chapter provided a summary of the report by presenting this methodology as an integrated framework. The chapter started with a detailed description of the function of each step in the methodology and the way in which the steps combine to generate a forecast. This was followed by an assessment of the methodology's data needs for each step. After this, two issues relating to methodology implementation were discussed: the sensitivity of the methodology to dynamic phenomena, and the methods by which the methodology accommodates joint choice decisions. The chapter concluded with recommendations for further research in order to improve the accuracy and usefulness of the methodology.

As this methodology is improved through application and further research, planners will be able to more efficiently allocate investments to the border in order to accommodate freight demand in a way that will help to reduce the friction in the economic relationship between the United States and Mexico, resulting in a better quality of life for the citizens of both nations.

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APPENDIX A:

HIGHLIGHTS OF U.S. CUSTOMS SERVICE DATA

APPENDIX A. HIGHLIGHTS OF U.S. CUSTOMS SERVICE DATA

With the assistance of Paul Rimmer and Frank Romanilli at the United States Custom Service, the University of Texas at Austin's Center for Transportation Research received a set of observations from selected ports of entry along the Texas border. Texas was selected because it serves as a conduit for much of the trade between the United States and Mexico. In 1990 over 70 percent of U.S.-Mexico bilateral trade moved through Texas ports of entry (Ref 12); in 1992, 64 percent of truck traffic crossed the border in Texas (Ref 3).

Five ports of entry were selected: El Paso, Laredo, Eagle Pass, Hidalgo, and Brownsville. These ports handle approximately 95 percent of traffic through the Texas border (Ref 3), and are consequently quite representative of border flows. For each of the ports, four months of data was collected: March, June, September, and December 1993. The months selected were equally spaced such that seasonal trends could be identified and accounted for, if necessary.

Each observation set included all waybills for northbound shipments inspected at a port of entry. This does not include all shipments. Some shipments are sent in-bond, and are not inspected until the shipment is received at the destination; therefore, these shipments are not reflected in this data. Moreover, not all Mexican cargo entering into Texas will traverse the land border at these ports, since there are nineteen other border crossings in Texas as well as the possibility for maritime and air transport. Therefore, this data set should not be interpreted as a complete representation of any aspect of the freight market.

The data was divided into files according to the month of observation and the port of entry. Misclassification of shipments either by month or by port of entry is likely impossible, as the customs service purges such observation-level data at the end of each month, and since each port reports their traffic individually. Each observation was unique according to its tariff schedule classification. In other words, if one shipment had four different commodities, it would be listed with four observations in this data set. Within each data set, the following information was provided for each observation:

Transportation Mode. This is a two-digit number, with the first number referring to the method of carriage and the second number referring to the type of cargo handling (i.e. containerized vs. bulk). Some shipments — a very small percentage — had missing numbers for transportation mode; these were assumed to be truck shipments.

City or State of Origin. This city information needs to be approached with care, because it may not reflect the shipment's true production location. For LTL or intermodal shipments, the city of origin may reflect the location of a consolidation or transfer terminal. For corporations with multiple production facilities, the city may be listed as the corporation's headquarters, whether the shipment originated there or not.

Ten-Digit Harmonized Tariff Schedule Classification. The first two digits correspond to the chapter number, which is a general classification of the type of commodity. The 99 chapters are divided into 22 sections, which correspond to aggregations of these commodities. One difficulty with classifying goods is the use of special classifications, Chapter 98. These classifications refer to variances in tariffs as well as to value-added processes, such as those found at maquiladoras.

Value Added. In U.S. dollars, this is the value corresponding to the item uniquely specified by each classification.

Weight. In kilograms, this is the vehicle weight for the vehicle carrying this unique item.

An entry in the data set might consist of the following:

20 MEXICO CITY/D.F. 2210603050 1300 14000 1

This is a rail (mode=20) observation from Mexico City. This observation can be classified under Chapter 22 ("Beverages") and has a value-added of $1,300, and is part of a shipment that weighs 14,000 kg. For complete chapter descriptions, please consult the Harmonized Tariff Schedule, published by the United States International Trade Commission.

Value-Added Processes

The difficulty in using this data set is to ascertain how vehicles are defined according to shipments. In addition, assembly processes performed at maquiladoras may take products from different classifications and combine them into yet a different classification. Because the weight entry corresponds to the weight of an entire shipment, one could speculate that consecutive observations sharing the same origin and mode and weight but having different tariff numbers would imply the same shipment. This sounds reasonable, but it will not always true. Nevertheless, for most Chapter 98 observations, this was the method used to properly assign "value-added" processes. Such an accounting is necessary because Chapter 98 has the highest aggregate value of any chapter surveyed, and it does not uniquely correspond to any commodity. Adjustments were made to reclassify Chapter 98 observations in an appropriate manner, as listed in Table A-1.

Table A-1. Tariff code adjustments

Reported HTS Code	New Chapter No.
9801001082	82
9801001084	84
9801001085	85
9801001087	87
9801001088	88
9801001090	90

Data Analysis

Data was processed and analyzed using SAS for Windows. Because of the difficulty of discerning where one shipment ends and another begins, value was used over tonnage as unit of measure for analyzing volumes of trade flows. Dollar flows were annualized by multiplying each cell by 365 and dividing by 122, corresponding to the number of days in the observed months against the number of days in the year. Some tables have a measure of seasonality. This was developed by calculating shares of traffic for each month studied and computing the standard deviation of those shares. This was found to result in the clearest definition of breakpoints in seasonal character. The breakpoints are as follows:

Table A-2. Definitions of seasonality

Classification	Range
None	X < 0.04
Low	0.04 ≤ X < 0.10
Moderate	0.10 ≤ X < 0.25
High	0.25 ≤ X < 0.50

Instead of dissecting each aspect of the data presented in the following tables, it is perhaps more interesting to focus on selected general trends which the data highlights. First, northbound shipments are directed to a port of entry based on minimizing distance. Because of infrastructure quality as well as accessibility, it is hypothesized — generally correctly — that carriers will select ports of entry which will allow them to get on U.S. infrastructure as soon as possible. In other words, the selection of a port of entry appears independent of both port congestion and shipment destination.

In correlation with this first statement, it should be observed that there are well-defined trade corridors. Laredo has a natural "corridor" to the industrial heart of Mexico, especially Monterrey, which causes it to attract most exports produced in that area. Hidalgo and Brownsville, on the other hand, attract shipments from states on the Gulf Coast, which are more likely to be agricultural or seasonal in nature than those produced in other regions of Mexico. While it is true that certain customs ports of entry are better equipped to handle certain shipments than others, this is probably due to staffing and equipment assignments corresponding to the routing patterns of carriers.

Table A-3. Top origins for northbound shipments through El Paso

City	State	Total ($M)	Share %	Cum %	StDev	Seasonality	Truck	Rail	Other
Juarez	Chihuahua	5,361.3	66.72%	66.72%	0.017	None	100%	0%	0%
Chihuahua	Chihuahua	959.5	11.94%	78.66%	0.028	None	94%	0%	6%
El Paso	U.S.	482.3	6.00%	84.66%	0.031	None	100%	0%	0%
Torreon	Coahuila	260.9	3.25%	87.91%	0.064	Low	84%	16%	0%
Nuevo Zaragoza	Chihuahua	155.0	1.93%	89.84%	0.042	Low	100%	0%	0%
Osaka	Japan	95.7	1.19%	91.03%	0.274	High	100%	0%	0%
Buenaventura	Chihuahua	48.9	0.61%	91.64%	0.059	Low	100%	0%	0%
Aguascalientes	Aguascalientes	46.0	0.57%	92.21%	0.079	Low	100%	0%	0%
Mexico City	Distrito Federal	45.8	0.57%	92.78%	0.091	Low	66%	34%	0%
Ascension	Chihuahua	39.9	0.50%	93.28%	0.075	Low	95%	5%	0%
Top Ten		**7,495.3**	**93.28%**		**0.017**	**None**	**98%**	**1%**	**1%**
Other		540.2	6.72%		0.055	Low	95%	5%	0%
Total		**8,035.5**	**100.00%**		**0.018**	**None**	**98%**	**1%**	**1%**

Third, modal choice appears to be largely dependent on distance and commodity type. Laredo and Eagle Pass are the only ports with significant amounts of multimodal traffic. Laredo's multimodal traffic seems to occur because most of its traffic originates in interior Mexico, where rail's better line-haul performance would make it more attractive than motor carriers. For Eagle

Pass, the modal split seems generally distance-based, although some origins do not fit this pattern, such as Saltillo-Ramos Arizpe.

Table A-4. Top origins for northbound shipments through Laredo

City	State	Value ($M)	Share %	Cum %	StDev	Seasonality	Truck	Rail
Mexico City	Distrito Federal	2,599.9	32.37%	32.37%	0.046	Low	27%	73%
Nuevo Laredo	Tamaulipas	790.4	9.84%	42.21%	0.019	None	99%	1%
Monterrey	Nuevo Leon	656.1	8.17%	50.38%	0.008	None	97%	3%
Apodaca	Nuevo Leon	306.7	3.82%	54.20%	0.020	None	91%	9%
Aguascalientes	Aguascalientes	287.8	3.58%	57.78%	0.047	Low	100%	0%
San Nicolas de los Garza	Nuevo Leon	227.1	2.83%	60.61%	0.028	None	96%	4%
Garcia	Nuevo Leon	213.0	2.65%	63.26%	0.022	None	92%	8%
Mexico	Edo de Mexico	185.8	2.31%	65.58%	0.061	Low	85%	15%
Saltillo-Ramos Arizpe	Coahuila	184.8	2.30%	67.88%	0.131	Moderate	77%	23%
San Luis Potosi	San Luis Potosi	169.6	2.11%	69.99%	0.119	Moderate	62%	38%
Top Ten		**5,621.1**	**69.99%**		**0.024**	**None**	**62%**	**38%**
Other		2,410.4	30.01%		0.025	None	89%	11%
Total		**8,031.5**	**100.00%**		**0.016**	**None**	**70%**	**30%**

Table A-5. Top origins for northbound shipments through Eagle Pass

City	State	Total ($M)	Share %	Cum %	StDev	Seasonality	Truck	Rail
Piedras Negras	Coahuila	126.1	26.15%	26.15%	0.032	None	100%	0%
Saltillo-Ramos Arizpe	Coahuila	111.7	23.17%	49.32%	0.471	High	5%	95%
Sabinas	Nuevo Leon	47.4	9.83%	59.15%	0.027	None	100%	0%
Mexico City	Distrito Federal	37.6	7.79%	66.94%	0.171	Moderate	2%	98%
Monclova	Coahuila	31.4	6.52%	73.46%	0.239	Moderate	56%	44%
Torreon	Coahuila	18.5	3.84%	77.31%	0.027	None	88%	12%
Mexico	Edo de Mexico	15.7	3.26%	80.57%	0.251	High	0%	100%
Belize City	*Central America*	*15.0*	*3.10%*	*83.67%*	*0.059*	*Low*	*100%*	*0%*
Guadalajara	Jalisco	11.7	2.43%	86.10%	0.032	None	99%	1%
Allende	Coahuila	10.7	2.21%	88.31%	0.173	Moderate	100%	0%
Top Ten		**425.9**	**88.31%**		**0.134**	**Moderate**	**59%**	**41%**
Other		56.4	11.69%		0.071	Low	48%	52%
Total		**482.3**	**100.00%**		**0.126**	**Moderate**	**58%**	**42%**

Table A-6. Top origins for northbound shipments through Hidalgo

City	State	Total ($M)	Share %	Cum %	StDev	Seasonality	Truck	Rail
Reynosa	Tamaulipas	1,132.7	75.24%	75.24%	0.031	None	100%	0%
Irapuato	Guanajuato	28.8	1.91%	77.15%	0.094	Low	100%	0%
Matehuala	San Luis Potosi	25.8	1.71%	78.86%	0.034	None	100%	0%
Apodaca	Nuevo Leon	23.9	1.59%	80.45%	0.068	Low	100%	0%
Martinez de la Torre	Veracruz	19.8	1.32%	81.77%	0.134	Moderate	100%	0%
Leon	Guanajuato	19.4	1.29%	83.06%	0.032	None	100%	0%
Mexico City	Distrito Federal	17.5	1.16%	84.22%	0.050	Low	100%	0%
Villagran	Guanajuato	16.2	1.08%	85.30%	0.106	Moderate	100%	0%
Buenavista de Cuellar	Guerrero	14.1	0.93%	86.23%	0.047	Low	100%	0%
Guadalajara	Jalisco	11.1	0.74%	86.97%	0.044	Low	100%	0%
Top Ten		**1,309.3**	**86.97%**		**0.025**	**None**	**100%**	**0%**
Other		196.1	13.03%		0.050	Low	100%	0%
Total		**1,505.4**	**100.00%**		**0.019**	**None**	**100%**	**0%**

Table A-7. Top origins for northbound shipments through Brownsville

City	State	Total ($M)	Share %	Cum %	StDev	Seasonality	Truck	Rail
Matamoros	Tamaulipas	1,944.7	76.13%	76.13%	0.023	None	92%	8%
Mexico City	Distrito Federal	181.6	7.11%	83.24%	0.042	Low	99%	1%
Reynosa	Tamaulipas	79.3	3.11%	86.35%	0.274	High	94%	6%
Guadalupe	N. Leon/Zac.	75.8	2.97%	89.32%	0.050	Low	100%	0%
Valle Hermoso	Tamaulipas	72.5	2.84%	92.16%	0.077	Low	100%	0%
Campeche	Campeche	22.7	0.89%	93.05%	0.114	Moderate	100%	0%
Tampico	Tamaulipas	19.6	0.77%	93.81%	0.105	Moderate	100%	0%
Matehuala	San Luis Potosi	14.7	0.58%	94.39%	0.069	Low	100%	0%
Cd. del Carmen	Campeche	14.3	0.56%	94.95%	0.066	Low	100%	0%
Rio Bravo	Tamaulipas	12.4	0.49%	95.44%	0.027	None	100%	0%
Top Ten		**2,437.7**	**95.44%**		**0.014**	**None**	**94%**	**6%**
Other		116.5	4.56%		0.041	Low	94%	6%
Total		**2,554.3**	**100.00%**		**0.014**	**None**	**94%**	**6%**

Table A-8. Top fifty corridors for northbound freight

#: Origin	Port of Entry	Value ($M)	StDev	Seasonality	Truck	Rail	Other
1: Juarez	El Paso	5,357.7	0.017	No	100%	0%	0%
2: Mexico City	Laredo	2,597.3	0.046	Low	27%	73%	0%
3: Matamoros	Brownsville	1,946.5	0.024	No	92%	8%	0%
4: Reynosa	Hidalgo	1,134.5	0.031	No	100%	0%	0%
5: Chihuahua	El Paso	959.9	0.028	No	94%	0%	6%
6: Nuevo Laredo	Laredo	790.7	0.019	No	99%	1%	0%
7: Monterrey	Laredo	655.9	0.008	No	97%	3%	0%
8: El Paso	El Paso	481.9	0.031	No	100%	0%	0%
9: Apodaca	Laredo	307.1	0.019	No	91%	9%	0%
10: Aguascalientes	Laredo	287.5	0.047	Low	100%	0%	0%
11: Torreon/Gomez Palacio	El Paso	260.9	0.064	Low	84%	16%	0%
12: San Nicolas de los Garza	Laredo	226.8	0.028	No	96%	4%	0%
13: Garcia	Laredo	212.9	0.022	No	92%	8%	0%
14: Mexico City	Brownsville	181.7	0.042	Low	99%	1%	0%
15: Saltillo	Laredo	184.8	0.132	Moderate	77%	23%	0%
16: San Luis Potosi	Laredo	169.7	0.119	Moderate	63%	37%	0%
17: Nuevo Zaragoza	El Paso	155.1	0.043	Low	100%	0%	0%
18: Guadalajara	Laredo	148.2	0.022	No	98%	2%	0%
19: Queretaro	Laredo	143.0	0.111	Moderate	77%	23%	0%
20: Tlaquepaque	Laredo	138.7	0.020	No	100%	0%	0%
21: Torreon/Gomez Palacio	Laredo	139.6	0.062	Low	62%	38%	0%
22: Toluca	Laredo	130.8	0.073	Low	64%	36%	0%
23: Piedras Negras	Eagle Pass	125.9	0.031	No	100%	0%	0%
24: Saltillo	Eagle Pass	111.8	0.471	High	5%	95%	0%
25: Santa Catarina	Laredo	102.4	0.122	Moderate	100%	0%	0%
26: Osaka	El Paso	95.7	0.274	High	100%	0%	0%
27: Guadalupe (NL)	Laredo	92.6	0.091	Low	100%	0%	0%
28: Reynosa	Brownsville	79.3	0.274	High	94%	6%	0%
29: Guadalupe (?)	Brownsville	75.8	0.050	Low	100%	0%	0%
30: Leon	Laredo	73.4	0.062	Low	100%	0%	0%
31: Valle Hermoso	Brownsville	72.5	0.077	Low	100%	0%	0%
32: Mexico City	El Paso	45.8	0.091	Low	66%	34%	0%
33: Celaya	Laredo	61.2	0.083	Low	98%	2%	0%
34: Guadalupe (?)	Laredo	57.8	0.124	Moderate	100%	0%	0%
35: Victoria	Laredo	54.0	0.080	Low	100%	0%	0%
36: Mexico City	Eagle Pass	37.6	0.171	Moderate	2%	98%	0%
37: Irapuato	Laredo	48.9	0.107	Moderate	100%	0%	0%
38: Buenaventura	El Paso	48.9	0.059	Low	100%	0%	0%
39: El Salto	Laredo	48.8	0.069	Low	95%	5%	0%
40: Sabinas	Eagle Pass	47.4	0.027	No	100%	0%	0%
41: Aguascalientes	El Paso	46.0	0.079	Low	100%	0%	0%
42: Ascension	El Paso	39.9	0.075	Low	95%	5%	0%
43: Cordoba	Laredo	39.6	0.126	Moderate	100%	0%	0%

Table A-8. Top fifty corridors for northbound freight (continued)

44: Xalapa	Laredo	39.5	0.142	Moderate	100%	0%	0%
45: Delicias	El Paso	39.1	0.042	Low	95%	5%	0%
46: Puebla	Laredo	38.6	0.031	No	98%	2%	0%
47: Camargo	El Paso	38.3	0.016	No	100%	0%	0%
48: Cuahtemoc	El Paso	36.7	0.024	No	100%	0%	0%
49: Tehuacan	El Paso	36.2	0.070	Low	98%	2%	0%
50: Tampico	Laredo	35.1	0.045	Low	100%	0%	0%

APPENDIX B:

SUMMARY OF STUDIES IN MODAL CHOICE

APPENDIX B. SUMMARY OF STUDIES IN MODAL CHOICE

Many studies have reviewed the characteristics that shippers consider most important in modal choice decisions. Table B-1 cites 23 of these studies, identifying the year of publication for each study, the choice decision under examination, the number of attributes considered, the way in which respondents were asked to rank attributes, and the five most important factors.

Table B-1. Summary of studies in modal choice

Author	Year	Sample	Selection Decision	No. of Factors	Ranking Method	Top Five Most Important Factors
American Association of Railroads (cited in Ref 88)	1962	U.S. shippers	Modal Choice	9	Rate each factor in importance	Dependability of delivery Total transit time Freight rates Loss and damage Special equipment
Sharp (Ref 124)	1971	125 shippers in Birmingham [UK]	Modal Choice	9	–NA–	Speed of delivery Loss and damage Special equipment National coverage Packaging costs
Bardi (Ref 125)	1973	Shippers of household goods	Modal Choice	9	Rank ordering	Reliability Security Satisfaction Equipment availability Time
Canadian Transportation and Distribution (Ref 126)	1973	648 traffic and distribution managers in Canada	Modal Choice	12	Rank ordering	Total transit time On-time performance Freight charges Door-to-door service Shipment tracing
Evans and Southard (Ref 101)	1974	210 manufacturers, wholesalers, and retailers in Oklahoma	Motor carrier selection	28	1-to-5 scale (1=most important)	Dependability of service Total transit time Carrier's ability to trace quickly Past performance of carrier Loss and damage experience with carrier

Table B-1. Summary of studies in modal choice (cont.)

Saleh and Das (Ref 89)	1974	454 U.S. traffic executives	Motor carrier selection	15[i]	Name most important factor	Consistent on-time performance Reliable pick-up, special order handling LTL handling Availability of equipment Shipment tracing
Stock (Ref 127)	1976	87 distribution executives in three industries	Modal choice	10	1-to-100 scale (100=very important)	Consistent on-time pick-up and delivery Freight charges Transit time Points served by mode Frequency of service
Gilmour (Ref 128)	1976	17 shippers on Sydney-Melbourne corridor	Modal choice	27[ii]	Select top five in importance (1=most important)	Cost Delivery time Shipment size Product characteristics Services provided by carrier
McGinnis (Ref 129)	1979	351 traffic executives	Modal choice	7	1-to-5 scale (1=most important)	Speed and Reliability Rates Loss and Damage External Market Influences Inventories
Bruning and Lynagh (Ref 99)	1984	185 distribution managers within the U.S.	Modal choice	7	0-to-10 scale (10=most important)	Pick-up and delivery performance Carrier linehaul performance Rates and charges Tracing and expediting Special service and equipment
Chow and Poist (Ref 98)	1984	207 traffic and distribution managers	Modal choice	22	Rate each factor in importance	Rates[iii] Transit time reliability Door-to-door transit time Equipment availability Frequency of service
Brand and Grabner (Ref 63)	1985	Survey of traffic and distribution in managers in three industries	Modal choice	20	0-to-10 scale (10=most important)	Service consistency Competitive rates Reliable pick-up and delivery Past experience with carrier Door-to-door transit time

Table B-1. Summary of studies in modal choice (cont.)

Quinn (Ref 130)	1987	Nearly 200 shippers	Modal Choice	13[iv]	1-to-5 scale (5=most important)	Reliable pick-up and delivery Shipment tracing Flexibility Geographic coverage Insurance
Bardi, Bagchi, Raghunathan (Ref 90)	1989	296 shipping executives	Motor Carrier Selection	18	1-to-5 scale (1=most important)	Time reliability Door-to-door rates Door-to-door transit time Willingness to negotiate rates Carrier's financial stability
Foster and Strasser (Ref 102)	1990	46 U.S. shippers	Modal Choice	11	Rank ordering (1=most important)	Schedule reliability Willingness to negotiate service Willingness to negotiate rates Door-to-door rates Door-to-door transit time
Abshire and Premeaux (Ref 103)	1991	94 shippers	Motor Carrier Selection	35	1-to-5 scale (5=most important)	Reliable delivery Reliable pick-up Carrier response in emergency situations Door-to-door transit time Carrier's financial stability
Morash and Calantone (Ref 131)	1991	128 traffic managers	Railroad Selection	13	1-to-5 scale (5=most important)	On-time delivery Reliability Loss and damage Availability Accessibility
Murphy, Daley, and Dalenberg (Ref 104)	1991	104 international freight forwarders	Modal Choice	10	1-to-5 scale (5=most important)	Equipment availability Shipment information Low loss and damage Convenient pick-up and delivery times Door-to-door rates
Fawcett and Vellenga (Ref 4)	1992	228 purchasing managers at maquiladoras	Modal choice	8	1-to-5 scale (5=most important)	On-time performance Transit time Rates Order accuracy Equipment coordination
Thuermen (Ref 132)	1992	77 *Global Trade* subscribers	Modal choice	7	Name most important factor	Customer service Schedule reliability Past experience Transit time Equipment availability

Table B-1. Summary of studies in modal choice (cont.)

McDonald (Ref 81)'	1993	Survey of shippers in U.S.	Modal choice	17	1-to-5 scale (5=most important)	Quality of service Service reliability Quality of pick-up Equipment availability Customer service quality
Traffic Management (Ref 133)	1993	1,600 readers of *Traffic Management*	Modal choice	5	Assign 100 points to factors according to relevance	On-time pick-up and delivery Overall responsiveness Low loss and damage Billing accuracy Innovation & flexibility
Spizzíri (Ref 82)	1994	Survey of National Intermodal Association	Modal Choice	10	–NA–	Delivery quality Service reliability Equipment availability Low risk of service failure Transit time

Structure adapted from Murphy, Daley, and Dalenberg (Ref 104).

i Respondents were asked to list all factors that were considered in the modal choice decision.

ii See note i.

iii Factors are ordered according to the percentage of respondents who ranked a factor as “maximum,” “great,” or “some” importance in the modal choice decision.

iv No rate-based factors were considered.